Rees's
Manufacturing Industry
(1819-20)

Volume Two

A selection from
The Cyclopaedia; or Universal Dictionary of Arts, Sciences and Literature
by
ABRAHAM REES

Edited by Neil Cossons

DAVID & CHARLES REPRINTS

first published serially 1802–20
Notes on the dating of various issues are given in the Introduction
(see Volume 1)

Printed in Great Britain by
Redwood Press Limited, Trowbridge, Wiltshire.

Contents

List of Illustrations

CYCLOPÆDIA:

OR, A NEW

UNIVERSAL DICTIONARY

OF

ARTS and SCIENCES.

Cements and Lutes

CEMENTS and Lutes. Under this article may be mentioned the receipts for preparing ſome of the moſt uſeful ſubſtances of this kind, that are required in common chemical operations.

The uſes of lutes and cements are either to cloſe the joinings of chemical veſſels to prevent the eſcape of vapours and gaſſes during the proceſſes of diſtillation, ſublimation, and the like, or to protect veſſels from the action of the fire which might crack, or fuſe, or calcine them: or ſometimes to repair flaws and cracks, and for a variety of other ſmaller purpoſes.

The ſubject of *calcareous cements*, ſuch as mortar, tarras, and other ſubſtances uſed to cloſe the joinings of bricks or ſtones in buildings, will be mentioned in the following article.

When a lute is applied over the whole ſurface of a veſſel, (as to a glaſs retort when it is intended to be heated red hot) the proceſs is termed, *lorication* or *coating*. Iron furnaces are alſo *lined* or *coated* on the inſide with earth, to prevent the iron from being deſtroyed by the conſtant action of the fire.

From the vaſt variety of receipts for lutes and cements of different kinds, the following may be ſelected, which will anſwer moſt of the purpoſes of the experimental chemiſt.

To prevent the eſcape of the vapours of water, ſpirit, and liquors not corroſive, the ſimple application of ſlips of moiſtened bladder will anſwer very well for glaſs, and paper with good paſte for metal. Bladder, to be very adheſive, ſhould be ſoaked ſome time in water moderately warm, till it feels clammy; it then ſticks very well. If ſmeared with white of egg, inſtead of water, it adheres ſtill cloſer.

Another very convenient lute is linſeed meal, moiſtened with water, to a proper conſiſtence, well beaten, and applied pretty thick over the joinings of the veſſels. This immediately renders them tight, and the lute in ſome hours dries to a hard maſs. Almond paſte will anſwer the ſame purpoſe.

The uſe of the above lute is ſo extenſive, that no other is required in cloſing glaſs veſſels in preparing all common diſtilled liquors; and it will even keep in ammonia, and acid gaſſes, for a longer time than is required for moſt experimental purpoſes. It begins to ſcorch and ſpoil at a heat much above boiling, and therefore will not do as a fire lute. It is ſtill firmer, and dries ſooner when made up with milk, or lime water, or weak glue.

A number of very coheſive cements impervious to water and moſt liquids and vapours, and extremely hard when once ſolidified, are made by the union of quick-lime with many of the vegetable or animal mucilaginous liquors. The variety of theſe is endleſs. We may firſt mention the following, as it has been extenſively employed by chemiſts for centuries. Take ſome whites of eggs with as much water, beat them well together, and ſprinkle in ſufficient ſlaked lime, to make up the whole to the conſiſtence of thin paſte. The lime ſhould be ſlaked by being once dipped in water and then ſuffered to fall into powder, which it will do ſpeedily with great emiſſion of heat, if well burnt. This cement ſhould be ſpread on ſlips of cloth, and applied immediately, as it hardens or ſets very ſpeedily. While hardening it may be of uſe to ſprinkle over it ſome of the lime in fine powder. This cement is often more ſimply and as conveniently managed, by ſmearing ſlips of linen on both ſides with white of egg, and when applied to the joining of the veſſels ſhaking ſome powdered lime over it. It then dries very ſpeedily.

Another lute of the ſame kind, and equally good, is made by uſing a ſtrong ſolution of glue to the lime inſtead of the white of egg. It ſets equally ſoon, and becomes very hard. A mixture of liquid glue, white of egg, and lime, makes

the *lut d'ane*, which is ſo firm, that broken veſſels united with it, are almoſt as ſtrong as when ſound. None of theſe lutes, however, will enable theſe veſſels to hold liquids for any great length of time. Milk or ſtarch, with lime, make a good, but leſs firm lute.

A very firm and ſingular lute of this kind is made by rubbing down ſome of the pooreſt ſkimmed milk cheeſe with water, to the conſiſtence of thick ſoup, and then adding lime, and applying as above. It anſwers extremely well. Lime and blood, with a ſmall quantity of brick-duſt, or broken pottery, ſtirred in, is uſed in ſome places as a very good water-cement for cellars and places liable to damp.

Paris-plaſter, mixed with egg, milk, glue, ſtarch, or any mucilaginous liquor, alſo makes a good lute.

Some artiſts mix other earths with the above materials. Thus a very good cement is made with equal parts of clay and lime, about $\frac{1}{3}$ of flour and white of egg; or, as is uſed by many of the aqua fortis-makers, a mixture of colcothar lime and white of egg.

All the above-mentioned cements, with lime, become very hard, by drying, inſomuch that they cannot be ſeparated from glaſs veſſels without the help of a ſharp knife and ſome violence; and hence delicate veſſels, and long thin tubes cemented with it, are apt to break, when the apparatus is taken down, and ſometimes even by the mere force of contraction in ſetting. It is a great advantage, however, that they may be applied immediately to any accidental crack or failure of the lute already on, notwithſtanding a ſtream of vapour is burſting through; and in large diſtillations it is of advantage always to have ſome of the materials at hand.

Theſe lutes will not confine very corroſive acid vapours perfectly, for a great length of time, but will anſwer for other purpoſes, particularly where a complicated apparatus is to be kept ſteadily united and air tight. They will bear nearly a red heat without material alteration.

Another kind of lute, which is the moſt perfect for confining acid vapours for any length of time, and which never hardens to an inconvenient degree, is the *fat lute*, as it is called. This is made by taking any quantity of good clay, tobacco-pipe clay, for example, thoroughly dry, but not burnt, powdering it in an iron mortar, mixing it gradually with drying linſeed oil, and beating them together for a long time to the conſiſtence of thick paſte. Much manual labour is required, and it ſhould be continued till the maſs no longer adheres to the peſtle. Then make the edges of the glaſs or other veſſel, where it is to be uſed, perfectly dry, and apply the lute carefully, and it will ſtand the longeſt proceſs without failing. This grows firm enough to retain its place, and to hold the veſſels together, but may readily be ſeparated by a knife. This lute much improves in adheſiveneſs by long keeping, which ſhould be in a covered pan in a cool cellar. When wanted, it regains ſufficient ductility, merely by beating for a minute or two, or by the help of a few drops more of the oil. Good glaziers putty, which is made of chalk, beat up with drying linſeed oil, much reſembles the fat lute in quality.

Another ſpecies of lute is that which is commonly applied round glaſs retorts, when diſtillation with a full red heat is wanted, to protect them from the ſudden action of the fire, and to give them firmneſs, and to enable them to bear this heat without flattening or falling together, when red hot, or melting with the fuel. A glaſs veſſel, ſo prepared, with a thick earthen coating, may be conſidered as an earthen veſſel glazed on the inſide. The ſubſtance uſed is a mixture of ſand, with juſt ſufficient clay to make it adhere together, beat up with ſome kind of fibrous matter, ſo as mechanically to increaſe the tenacity. A natural earthy mixture of the kind is Windſor loam, or an equally good one may be formed with coarſe ſand and clay, or better with fragments of pottery coarſely ground, (the fine part being ſeparated by ſifting, and rejected,) mixed with more or leſs clay, according to the quality, ſo that it will juſt mould together when wet. For the fibrous matter, ſome uſe horſe-dung, which appears to be the beſt, others chopped ſtraw or chaff, others chopped horſe, or cow-hair, or tow, all of which anſwer the ſame purpoſe. A ſmall quantity of theſe will ſuffice. Beaumé recommends about an ounce of cow's hair to five pounds of the earthy mixture. A good deal of water ſhould be added, when the materials are mixed, and much manual labour is required to diffuſe the hair equally through the mixture. To apply it to a glaſs veſſel, a retort, for example, take a ſufficient quantity of the lute, ſpread it out flat on a table, lay the bottom of the retort on the middle of the maſs, and then turn up the edges of the flat cake, and bring it over the reſt of the glaſs, preſſing it down with the fingers, till it applies uniformly and cloſely. By this method the lute is without ſeam, and is much more likely to dry in the fire without cracking. Or elſe, bring the lute, with ſufficient water, to the conſiſtence of thick ſoup, dip the retort in, and it will come out thinly coated. Turn it round before the fire, and, when dry, dip it again in the lute, to give a ſecond coating, and ſo on, to the required thickneſs, which may be from $\frac{1}{4}$ to $\frac{1}{2}$ an inch. A lute ſimilar to this is uſed as a lining to iron furnaces, to confine the fire, and prevent the iron from conſuming by the conſtant heat. This lute is juſt ſo fuſible as to begin to agglutinate in a full red heat; and hence, if it remains found till thus hot, it will form an impenetrable coating to the glaſs within, from which it cannot afterwards be detached. The covers of crucibles and other veſſels intended to bear fire may be luted with this earthy mixture. It is rendered ſtill leſs liable to crack on the firſt heating, if, when thoroughly dry, it is ſmeared with linſeed oil.

Sometimes, however, a ſtill more fuſible compound is wanted, particularly where very volatile and penetrating ſubſtances are diſtilled from an earthen veſſel. Theſe veſſels are neceſſarily porous, to a certain degree, independent of any caſual cracks, from which the larger earthen veſſels are ſeldom entirely free. When phoſphorus, for example, is prepared, by ſtrongly heating charcoal and phoſphoric acid in one of theſe retorts, the vapour of the phoſphorus penetrates through the pores, when thoroughly red hot, and much of it is loſt. Nor will the laſt-mentioned luting entirely prevent this, ſo that it is a great ſaving to cover the retort firſt with a thin coat of a fuſible glazing, which will melt on the ſurface as ſoon as red-hot, and cloſe every opening. This glazing may be made by a variety of fluxes added to the proper doſe of clay and earth, and mixed into a thin paſte and applied to the retort with a bruſh. The following management is recommended by Mr. Willis, a practical chemiſt, (Repertory, vol. i.) in diſtillation with large earthen retorts. Diſſolve one ounce of borax in half a pint of boiling water, and add as much ſlaked lime as will make it into a thin paſte. Spread it over the retort with a bruſh, and, when dry, apply over the whole a lute of ſlaked lime and linſeed oil, beaten till it is perfectly plaſtic. This becomes dry in a day or two, and is then fit for uſe. Stone retorts may thus be uſed ſeveral times with ſafety, (always renewing the oil and lime-lute); whereas, in the common way, and even with the clay and hair-lute, they generally crack when cooling, or on being heated a ſecond time. If, during the operation, the retort ſhould crack, Mr. Willis adviſes to ſpread ſome of the oil compoſition thickly on the

part, and ſprinkle ſome flaked lime over the whole, which will prevent the further eſcape even of the penetrating vapour of phoſphorus, and may be ſafely applied even when the retort is red-hot. When prepared ſomewhat thicker, it is very proper as a general lute for a variety of purpoſes, and will never harden ſo as to break the veſſel.

Often a fire lute is required to join the covers to crucibles, or for ſimilar purpoſes, ſo as to keep them air-tight when hot. A very valuable compoſition of the kind is made of glaſs of borax, brick-duſt and clay finely powdered together, and mixed with a little water when uſed. No very great nicety is required in the proportions, but about a tenth of borax is quite ſufficient to bring the earths to that ſtate of ſemi-vitrification which is deſired. Litharge may alſo be uſed inſtead of borax, but the latter is by far the beſt, as it promotes that thin ſpreading fuſion which is beſt calculated to be equally applied over an uneven ſurface; and beſides, if a portion of the litharge lute were to drop into the crucible it might poſſibly be reduced, and lead introduced into the reſults of the experiments.

A cement, ſaid to be uſeful to ſtop cracks of iron veſſels intended to be ſtrongly heated, is made of ſix parts of clay, one of iron filings, and linſeed oil enough for the mixture

Another ſpecies of cement is what is termed by the French *Maſtich chaud,* and conſiſts of different kinds of oily and reſinous ſubſtances, liquid when hot, and which become more or leſs ſolid by cooling. They are uſeful for a variety of miſcellaneous purpoſes, for experiments with gaſſes over water or mercury, and others where only a very moderate warmth is uſed, and where it is of importance to keep out air and water. Theſe will alſo confine acid vapours, but not the vapours of alcohol, turpentine, or eſſential oils, which diſſolve moſt reſinous ſubſtances. Moſt of them will ſtick very well to glaſs. Common ſealing-wax is one of the moſt uſeful of theſe cements. A cheaper and leſs brittle cement is made ſimply by melting bees wax with about one eighth of common turpentine. This may be made up into ſticks to be uſed when wanted, being firſt melted or ſpread evenly with a hot iron. A greater proportion of turpentine renders this lute ſofter and more fuſible, but ſomewhat pliable.

A very firm cement is made by four parts of roſin, one of bees wax, and when melted, one part of fine brick duſt, ſtirred in. This adheres with extreme firmneſs. Table knives are cemented to their handles by this mixture, and turners uſe a ſimilar compoſition in ſome fine works to fix them to the lathe.

Chaptal found, after many trials, that the penetrating vapours of ſulphureous acid in the manufacture of alum were completely confined in a wooden chamber lined very carefully with a mixture of equal parts of pitch, turpentine, and wax boiled till all the eſſential oil was diſſipated (which was known by the ceſſation of the bubbles) applied melted to the wood, and ſpread with a hot trowel over the joints. Vintners ſtop leaks in their caſks with melted ſuet rubbed over when cooling with ſifted wood-aſhes, or previouſly mixed with the aſhes in melting.

The uſe of gum arabic diſſolved in water, for cementing paper labels to bottles, and a great variety of miſcellaneous purpoſes, is known to every one. A ſtill better cement for the ſame uſe is iſinglaſs diſſolved in vinegar to a pretty thick conſiſtence when warm. This congeals on cooling, and before it is uſed it ſhould be gently warmed.

Many of the varniſhes and oil paints are employed in rendering veſſels air and water tight. Thus when canvas bags are faſtened to a ſtop-cock tube for air-holders, the joining is made perfectly tight by tying over it ſlips of cloth or bladder ſoaked in ſpirit varniſh.

The following cement is ſaid to be very uſeful in joining together glaſs or ſteel. Take of maſtich five or ſix bits as big as peas, diſſolve in as much alcohol as will render them liquid. In another veſſel diſſolve as much iſinglaſs (previouſly ſoaked in water) in brandy or rum, as will make two ounces by meaſure of a ſtrong glue, warm it, and incorporate with it by rubbing two or three ſmall bits of galbanum or ammoniacum and then the maſtich ſolution. Keep the cement in a bottle well ſtopped, and gently warm it before uſe.

Thoſe fuſible metal compounds uſed to unite pieces of metal form another totally diſtinct ſpecies of cements. Theſe are termed Solders, under which they will be deſcribed. See Cæment.

Cements, *calcareous.* In this article it is propoſed to give an account of the various cements uſed in building, into which lime enters as an eſſential conſtituent part; and in order to treat the ſubject with a degree of clearneſs, in ſome meaſure correſponding to its importance, it will be adviſable to arrange every kind of calcareous cement under one or other of the following three diviſions: firſt, ſimple calcareous cements: ſecondly, water cements: thirdly, maſtichs or maltha.

§ 1. *Simple calcareous cements.*

This ſection includes thoſe kinds of mortar which are employed in buildings on land; and generally conſiſt of lime, ſand, and freſh water.

It is well known that calcareous earths are converted, by burning, into what is called quick lime, which ſubſtance being wetted with water falls into a powder with great extrication of heat, and then acquires the property of uniting with ſand, and various other ſubſtances, and forming a ſolid maſs which becomes as hard and durable as moſt building ſtones. We have no means of aſcertaining by whom or at what time this valuable property of lime was diſcovered; but among the nations of antiquity the Romans appear to have made the moſt uſe of, and to have been moſt ſkilled in cementitious building.

The various kinds of marble, chalk, and lime-ſtone, as far as regards their uſe in cements, may be divided into two ſpecies; the firſt being pure or nearly pure carbonat of lime; the ſecond containing beſides from $\frac{1}{20}$ to $\frac{1}{12}$ of clay and oxyd of iron. Previous to burning or calcination, there are no external characters by which the ſimple lime-ſtones can be diſtinguiſhed from the argillo-ferruginous ones; but the former, whatever may have been their colour in a crude ſtate, become when calcined of a white colour, while the latter poſſeſs more or leſs of a light ochery tinge. The brown lime is by far the beſt for all kinds of cements; but the white varieties being more abundant, and allowing of a larger proportion of ſand, are generally made uſe of. It was an opinion of the ancients, and is ſtill commonly received among builders, that the hardeſt lime-ſtone, *cæteris paribus,* furniſhes the beſt lime; thus mortar was ſaid to grow as hard as the lime-ſtone of which it was compoſed, and hence marble was conſidered as ſuperior to common lime ſtone, and this latter to chalk. The experiments of Dr. Higgins and Mr. Smeaton, however, ſhow that this is entirely a miſtake; common chalk, and the hardeſt Plymouth marble, when ſimilarly treated, affording cements of equal firmneſs.

When carbonated lime has been thoroughly burnt, it is deprived of its water, and of all, or nearly all of its carbonic acid: if, in this ſtate, it is plunged into water, and immediately taken out again, the water which it has abſorbed

will occaſion the maſs to crack and become exceſſively hot, and at length to fall into an impalpable powder, much of the water being carried off in the form of ſteam during the proceſs. When lime has been thus ſlaked, if it is beaten up with a little water into a very ſtiff paſte and allowed to dry, it will be found that the white limes, whether from chalk or marble, never acquire any degree of hardneſs, that the brown limes become conſiderably indurated though not ſo much ſo as when mixed with ſand, and that ſhell lime (procured by calcining ſea ſhells), concretes into a firm, hard cement, well qualified for dry buildings, although it falls to pieces in water.

Lime-ſtone loſes about $\frac{4}{9}$ of its weight by burning, but ſhrinks in an inconſiderable degree; upon quenching, when fully burnt, it falls freely, and will produce ſomewhat more than double the quantity of powder or ſlaked lime, in meaſure, that the burnt lime-ſtone conſiſted of.

Quick-lime, by expoſure to the air, abſorbs carbonic acid with greater or leſs rapidity, as it is of a cloſe and hard, or ſoft and ſpongy texture; thus it gradually loſes its cementing properties and at length becomes totally unfit for the purpoſes of mortar. Hence, though ſtone-lime and chalk-lime are equally good, when perfectly burnt, and uſed freſh from the kiln, there is an important practical difference between them, as the chalk-lime abſorbs carbonic acid with much the greateſt facility.

A proper ſelection of ſand is of great importance in the compoſition of mortar; the ſharper and coarſer it is the better; as it requires a ſmaller proportion of lime, and makes a ſtronger cement than when fine grained and round ſand is made uſe of. Sea ſand requires to be well waſhed in freſh water to diſſolve out the ſalt with which it is mixed, otherwiſe the cement into which it enters never becomes thoroughly dry and hard.

The moſt advantageous proportions of lime and ſand in the compoſition of mortar is a point by no means ſettled. The Roman builders were accuſtomed to allow three parts of pit ſand, or two parts of river or ſea ſand to one of lime. In general, it may be affirmed, that it will be advantageous to uſe the largeſt quantity of ſand that can be introduced, preſerving the neceſſary degree of plaſticity. Mortar, in which the ſand predominates, requires leſs water in preparing, and therefore ſets ſooner; it is harder and alſo leſs liable to crack on drying than that in which lime prevails. Smeaton obſerves, that there is ſcarcely any but what, if well burnt and beaten, a load or meaſure of unſlaked lime will take two loads or meaſures of ſand. On purſuing this ſubject he ſoon found that, by good beating, the ſame quantity of lime would take in one meaſure of tarras and three of clean ſand, which ſeems to be the greateſt uſeful proportion, for on a further increaſe of the quantity of ſand, the mortar required ſo much more beating to bring it to a proper conſiſtence and toughneſs, that the labour became of more value than the ſaving of materials. Theſe obſervations agree very nearly with the experiments of Dr. Hutton.

The weakneſs of modern mortar compared to the ancient is a common ſubject of regret, and many ingenious men taking for granted, that the proceſs uſed by the Roman architects in preparing their mortar is one of thoſe arts which are now loſt, have employed themſelves in making experiments to recover it, inſtead of attending to the directions left us in the works of Pliny and Vitruvius, which, when illuſtrated by the actual practice of builders in various parts of Europe, ſeem to leave little or no doubt on the ſubject.

The characteriſtic of all modern artiſts, builders among the reſt, ſeems to be to ſpare their time and labour as much as poſſible, and to increaſe the quantity of the articles they produce, without much regard to their goodneſs; and perhaps there is no manufacture in which this is ſo remarkably exemplified as in the preparation of common mortar, eſpecially in London and its neighbourhood.

The peculiar badneſs of London mortar is to be attributed, both to the faulty nature of the materials, and the careleſs and haſty method of uſing them. The lime employed is the ſoft chalk-lime of Eſſex and Kent, which inſufficiently burnt at firſt, is conveyed a diſtance of ten or twenty miles and kept many days, without any precautions to prevent the acceſs of the external air; and thus before it is uſed, it has time to abſorb ſo much carbonic acid as nearly to loſe its cementing properties. It has been before obſerved, that though chalk, when perfectly burnt, is equally good as the hardeſt lime, it poſſeſſes ſome practical diſadvantages; it will fall into a coarſe powder on the application of water, when it is only partially calcined, which ſtone-lime will not, and the cores or unburnt lumps may be broken down by a blow with the ſpade, and are therefore very ſeldom rejected as they ought to be.

Sand, which is ſcarce and dear in London, is equally defective. This is pit ſand, but very different from the kind recommended by Pliny and Vitruvius; inſtead of being clean, large-grained, and ſharp, it is compoſed of ſmall round grains, and ſoiled with a large mixture of clay. Its fineneſs and ſmoothneſs cannot be amended, but by waſhing it well in running water the clay might unqueſtionably be got rid of, and this would be no trifling improvement, for Smeaton has ſhown, by direct experiment, that mortar of the beſt quality, when mixed with a ſmall proportion of unburnt clay, never acquires that hardneſs and dryneſs which, without this addition, it would ſpeedily have attained. Screened rubbiſh and the ſcrapings of the roads, conſiſting chiefly of gravel reduced to fine powder, are alſo uſed as ſubſtitutes for ſand with ſtill greater impropriety.

The method of preparing common mortar is alſo extremely imperfect. The lime being ſlaked by the addition of water, and the unburnt lime being broken down and mixed with the reſt, a quantity of dirty ſand is added, and the whole being incorporated by means of a ſpade, is reckoned to be fit for uſe; thus the principal point in the making of mortar, namely, beating the ingredients together, ſo as to mix them thoroughly, is ſlurred over in a haſty careleſs manner, and the reſult, as might be expected, is a crumbling maſs ſcarcely fit for uſe. The Roman builders, on the other hand, after they had mixed together the materials, employing for this purpoſe a ſmaller proportion of water than is cuſtomary at preſent, put the maſs into a large wooden mortar, and beat it till it ceaſed to adhere to the heavy wooden or iron peſtle which was uſed on the occaſion; a practice, which has long been followed by the Dutch with complete ſucceſs, as will be ſhewn in the next ſection.

Freſh made mortar, if kept under ground in conſiderable maſſes, may be preſerved for a great length of time without injury; and the older it is before it is uſed the better; the builder taking the precaution to beat it up afreſh, previous to uſing it; for it not only ſets ſooner, but acquires a greater degree of hardneſs, and is leſs apt to crack. A fact related by Mr. Smeaton, remarkably illuſtrates theſe points. Having had occaſion to take up a large flat ſtone of a cloſe grain, of about five feet ſquare, that had probably lain above a century at the bottom of a malt ciſtern, he found that it had been well bedded in mortar, which had become coagulated to the conſiſtence of cheeſe; but having never come to a perfect dryneſs, it ſo far retained its natural humidity, that he found it might, with ſome pains, be beaten up to mortar

without any addition of water; and afterwards being suffered to dry in the air, it set to a stony hardness, and appeared as good mortar as any which that part of the country produced. Pliny informs us, that the ancient Roman laws prohibited builders from using mortar that was less than three years old; and to this circumstance he expressly attributes the remarkable firmness of the oldest buildings in the city. A similar custom prevailed, and we believe still prevails in Vienna, requiring the mortar to be a year old before it is employed. But there is nothing which shows, in so striking a point of view, the advantage and necessity of beating mortar, and that the effect produced is owing to something more than a mere mechanical mixture of the ingredients, as the preparation of *grout*, or liquid mortar. This differs from common mortar only in containing a larger quantity of water, so as to be sufficiently fluid to penetrate the narrow irregular interstices of rough stone walls, and is generally made by diluting common mortar with water, either cold or hot. It not unfrequently happens, that this grout refuses to set, and at all times it is a long while in acquiring the proper hardness; but if, instead of common mortar, that which has been long and thoroughly beaten is employed, the grout will set in the space of a day, and soon after acquires a degree of hardness much superior to what is made in the common manner.

§ 2. *Water Cements.*

Although a well made mortar, composed merely of sand and lime, if allowed to dry, becomes impervious to water, so as to serve for the lining of reservoirs and aqueducts; yet if the circumstances of the building are such as to render it impracticable to keep out the water, whether fresh or salt, a sufficient length or time, the use of common mortar must be abandoned; for lime and sand, if mixed together in any proportions, and put, while soft, into water, will in a short time fall to pieces.

Among the nations of antiquity the Romans appear to have been the only people who practised building in water, and especially in the sea, to any great extent. The bay of Baiæ, like our fashionable watering places, was the summer resort of all the wealthy in Rome; who, not content with erecting their villas as near the shore as possible, were accustomed to construct moles, and form small islands, in the more sheltered parts of the bay, on which, for the sake of the grateful coolness, they built their summer houses and pavilions. They were enabled to build thus securely in the water by the fortunate discovery, at the neighbouring town of Puteoli, of an earthy substance, which, from this circumstance, was called *pulvis Puteolanus* (powder of Puteoli.) Puteolan powder, or as it is now denominated puzzolana, is a light, porous, friable mineral, of a red colour, and is generally supposed to derive its origin from concreted volcanic ashes, thrown out from Vesuvius, near to which mountain the town of Puteoli is situated. It seems to consist of a ferruginous clay, baked and calcined by the force of volcanic fire, and when mixed with common mortar, not only enables it to acquire a remarkable hardness in the air, but to become as firm as stone, even under water. The only preparation which puzzolana undergoes, is that of pounding and sifting, by which it is reduced to a coarse powder; in this state being thoroughly beaten up with lime, either with or without sand, it forms a mass of remarkable tenacity, which speedily sets under water, and becomes at least as strong as good freestone.

It has been before observed, that a composition of pure lime and sand alone will not harden under water, but limes containing a portion of clay possess this property in a considerable degree, and are therefore generally used in water building. The cement used by Mr. Smeaton, in the construction of the Eddystone lighthouse, was composed of equal parts by measure of slaked Aberthaw lime and puzzolana. The peculiar difficulties of this undertaking, exposed to the utmost violence of the sea, rendered these proportions advisable; but for works that are less exposed, such as locks and basons for canals, &c. the quantity of puzzolana may be considerably diminished. A composition of this kind, which has been found very effectual, is 2 bushels of slaked Aberthaw lime, 1 bushel of puzzolana, and 3 of clean sand; the whole being well beaten together will yield 4.67 cubic feet of cement.

The Dutch have practised building in water to a greater extent than any other nation of modern Europe; and to them is due the discovery of a cement admirably well adapted for this purpose, and called tarras or trass. This is nothing more than wakke, or cellular basalt, and is procured chiefly from Bockenheim, Frankfort on the Maine, and Andernach, whence it is transported down the Rhine in large quantities to Holland. This substance being, by grinding and sifting, reduced to the consistence of coarse sand, is used in the composition of mortar, with the blue argillaceous lime from the banks of the Scheldt, in the following method. They take of the quick-lime about the quantity which will be wanted during a week, and spread it in a kind of bason in a stratum of a foot thick, and sprinkle it with water. It is then covered with a stratum of about the same thickness of tarras, and the whole suffered to remain for two or three days, after which it is very well mixed and beaten, and formed into a mass, which is again left for about two days; it is then taken in small quantities, as it is wanted for daily consumption, which are again beaten previous to using. Thus is composed the celebrated tarras mortar with which the mounds and other constructions for the purpose of protecting the lowlands of Holland against the sea are cemented.

Tarras is frequently used in this country, being imported from Holland for that purpose. The proportions of the materials of the tarras mortar generally used in the construction of the best water works is the same as the Dutch practise. One measure of quick-lime, or two measures of slaked lime in the dry powder, is mixed with one measure of tarras, and both very well beat together, to the consistence of a paste, using as little water as possible. Another kind, almost equally good, and considerably cheaper, is made of two measures of slaked lime, one of tarras, and three of coarse sand; it requires to be beaten a longer time than the foregoing, and produces three measures and a half of excellent mortar. When the building is constructed of rough irregular stones, where cavities and large joints are to be filled up with cement, the pebble mortar may be most advantageously applied; this was a favourite mode of construction among the Romans, and has been used ever since their time in those works in which a large quantity of mortar is required. Pebble mortar will be found of sufficient compactness if composed of two measures of slaked argillaceous lime, half a measure of tarras, or puzzolana, one measure of coarse sand, one of fine sand, and four of small pebbles, screened and washed.

It is only under water that tarras mortar acquires its proper hardness; for if suffered to dry by exposure to the air, it never sets into a substance so firm as if the same lime had been mixed with good clean common sand, but is very friable and crumbly. Ash mortar is reckoned to be superior for works that are sometimes wet and sometimes dry, but tarras has the advantage when constantly under water. Tarras mortar when kept always wet, and consequently in a state most favourable to its cementing principle, throws out a

substance something like the concretions in limestone caverns called stalactites, which substance acquires a considerable hardness, and in time becomes so exuberant as to deform the face of the walls.

Although the cellular basalt is the only kind admitted into the preparation of Dutch tarras, yet it appears from some good experiments of Morveau on the subject, that the common compact basalt, if previously calcined, will answer nearly the same purpose. Great Britain is at a considerable annual expence in purchasing tarras from Holland; it may be worth while, therefore, to point out some of our domestic treasures of the same material. The compact basalt abounds in all the districts where coal is raised, and may therefore be procured easily, and calcined with the refuse coal, so as to be sold at a cheap rate. The Calton hill, adjoining to Edinburgh, consists almost entirely of cellular basalt, and being but at a short distance from the port of Leith, offers an inexhaustible abundance at a small cost.

In some parts of the Low Countries coal ashes are substituted for tarras with very good effect; of which the valuable *cendrée de Tournay* is a striking instance. The deep blue argillo-ferruginous limestone of the Scheldt is burnt in kilns with a slaty kind of pit-coal that is found in the neighbourhood. When the calcination of the lime is completed, the pieces are taken out, and a considerable quantity of dust and small fragments remains at the bottom of the kiln. This refuse consisting of coal ash mixed with about one-fourth of lime dust, is called the cendrée, and is made into a mortar with lime in the following method. About a bushel of the materials is put in any suitable vessel, and sprinkled with water just sufficient to slake the lime; another bushel is then treated in the same way, and so on till the vessel is filled. In this state it remains some weeks, and may be kept for a much longer time if covered with moist earth. A strong open trough, containing about two cubic feet, is filled about two-thirds full with the cement in the above state, and by means of a heavy iron pestle, suspended at the end of an elastic pole, is well beaten for about half an hour: at the end of this time it becomes of the consistence of soft mortar, and is then laid in the shade from three to six days, according to the dryness of the air. When sufficiently dry, it is beaten again for half an hour as before, and the oftener it is beaten the better will be the cement; three or four times, however, are sufficient to reduce the cement to the consistence of an uniform smooth paste; after this period it is apt to become refractory on account of the evaporation of its water, as no more of this fluid is allowed to enter the composition than what was at first employed to slake the lime. The cement thus prepared is found to possess the singular advantage of uniting in a few minutes so firmly to brick or stone, that still water may be immediately let in upon the work without any inconvenience, and by keeping it dry for 24 hours, it has nothing further to fear from the most rapid current.

A composition very similar to the preceding in materials, which are coal cinders and lime, though seldom prepared with any attention, is the blue mortar, commonly used in London for setting the coping of buildings, and other works much exposed to the weather.

Ash mortar is used in some parts of England. It is prepared by slaking two bushels of fresh burnt meagre lime, and mixing it accurately with three bushels of wood ashes: the mass is to lie till it is cold, and is then to be well beaten: in this state it will keep a considerable time without injury, and even with advantage, provided it is thoroughly beaten twice or thrice before it is used.

The scales of black oxyd, which are detached by hammering red-hot iron, and are therefore to be procured at the forges and blacksmiths shops, have been long known as an excellent material in water cements; but we believe that Mr. Smeaton was the first person who made any accurate experiments on their efficacy, compared with other substances. The scales being pulverised and sifted, and incorporated with lime, are found to produce a cement equally powerful with puzzolana mortar, if employed in the same quantity. Induced by the success of these experiments, Mr. Smeaton substituted roasted iron ore for the scales, and found that this also gave to mortar the property of setting under water; it requires, however, to be used in greater proportions than either tarras or puzzolana; two bushels of argillaceous lime, two of iron ore, and one of sand, being carefully mixed, produce 3.22 cubic feet of cement fully equal to tarras mortar. If the common white lime is made use of, it will be advisable to employ equal quantities of all the three ingredients.

With respect to the water used in the preparation of water cements, that of rivers or ponds where it can be had easily, is to be preferred to spring water; but for works exposed to the action of the sea, such as piers, light-houses, &c. it is usually more convenient and equally advantageous in other respects to use salt water.

Pumice stone, brick, and tile dust, are also recommended for water cements, but their only advantage seems to be an absorbent quality, which causes the mortar made with them to set sooner, and therefore acquire a greater hardness in the same time, than mortar composed of sand and lime alone, for they have no power of hardening under water.

The Loriot mortar is a composition which has acquired considerable celebrity in France, and has been employed in some large works. It was invented about 40 years ago by Mr. Loriot, who imagines that he has discovered the process used by the Romans. The principle of this invention consists in adding to any quantity of mortar made in the usual way with lime and sand, but prepared rather thinner than usual, a certain proportion of quick lime, in powder. The lime powder being well incorporated with the mortar, the mass heats, and in a few minutes acquires a consistence, equal to the best Paris plaster, and is as dry at the end of two days, as an ordinary cement after several months. It also, when the ingredients are well proportioned, sets without any cracks. The quantity of lime powder to be added, varies from $\frac{1}{4}$ to $\frac{1}{6}$ of the other materials, according to the qualities of the lime; too much burns and dries up the mass, and with too little, it loses its peculiar advantages; thus the proportions, a point of the utmost importance, can only be determined by experiment. It is its speedy desiccation which rendered the Loriot mortar useful as a water cement, for under water it has only the common properties of a composition of lime and sand of equal solidity; indeed for this purpose various substances, commonly used in cements, are recommended to be added, such as brick and tile powder, and forge scales. The following is an approved receipt. One measure of bricks exactly pounded, two measures of fine river sand, old slaked lime in sufficient quantity to make a mortar in the usual manner and sufficiently liquid to quench the lime powder which is added in about the same quantity as the pulverised brick.

It is sufficiently extraordinary, that a process, perfectly similar to that of M. Loriot, is described in a "Treatise on Building in Water, by George Semple," printed at Dublin, 1776. In discoursing on the good qualities of the roach-lime of Ireland, Mr. Semple remarks, that, "it has some useful qualities not much known among the generality of workmen, as, for instance, our lime-stone will make exceeding good tarras for water-works, for which purpose, you are

to prepare it thus. Get your roach-lime brought to you hot from the kiln, and immediately pound, or rather grind it, with a wooden maul, on a dry, boarded floor, till you make it as fine as flour; then, without loss of time, sift it through a coarse hair or wire sieve, and, to the quantity of a hod of your setting mortar, (which, on this account, ought to be poorer than ordinary,) put in two or three shovels-full of this fine flour of the roach-lime, and let two men, for expedition sake, beat them together with such beaters as the plasterer make use of, and then use it immediately. This, I can assure you, will not only stand as well, but is really preferable to any tarras." The memoir of M. Loriot was published in 1774, only two years previous to this treatise of Semple, who appears to have been a man rather of practice and experience than of reading: and, besides, in the book quoted from, he expressly, though incidentally, mentions his ignorance of the French language. We are justified therefore, in stating, that the knowledge of the advantages of mixing quick lime powder in mortar was not confined to M. Loriot, though it might be an original invention in him, and he was the first who drew public attention to the process, and used it in any considerable works.

§ 3. *Maltha, or Mastich.*

Under this term we include those calcareous cements of a more complicated kind, whose hardness appears to depend on the oily or mucilaginous substances that enter into their composition. The use of these is at present very limited, at least in Europe, but they were highly esteemed by the ancients, especially for stucco. The maltha of the Greeks seems to have been more simple than that employed by the Roman architects; at least we are informed that Panænus, the brother of Phidias, lined the inside of the temple of Minerva at Elis with a stucco, in which the usual ingredients, sand and lime, were mixed up with milk instead of water, some saffron being also added to give it a yellow tinge. The Roman maltha, according to Pliny, was prepared in the following manner. Take fresh burnt lime, slake it with wine, and beat it up very well in a mortar with hog's lard and figs: this cement, if well made, is excessively tenacious, and, in a short time, becomes harder than stone; the surface to which it is to be applied is to be previously oiled, in order to make it adhere. Another kind, almost equally strong, and considerably cheaper, was prepared by beating up together fine slaked lime, pulverized iron-scales and bullock's blood.

In the preparation of mastichs, as well as of every other kind of mortar, so much depends on the manipulation, and especially on the care which is taken to incorporate the ingredients by *long* beating, that those countries in which labour is of the least value possess, in general, the best mortar. Hence, no doubt, principally arises the unrivalled excellence of the mortar made by the Tunisians and other inhabitants of the northern coast of Africa, which, according to Dr. Shaw, is prepared in the following manner. One measure of sand, two of wood-ashes, and three of lime, being previously sifted, are mixed together, and sprinkled with a little water; after the mass has been beaten some time a little oil is added: the beating is carried on for three days successively, and, as the evaporation in that hot climate is considerable, the cement is kept at the proper degree of softness by the alternate addition of very small quantities of water and oil. The cement being completed, is applied in the usual manner, and speedily acquires a stony hardness. The last species of maltha that we shall mention is the celebrated chunam of India, where it has been used from time immemorial. The method in which it is prepared at Madras is as follows.

Take 15 bushels of pit sand, and 15 bushels of stone-lime; slake the latter with water; and when it has fallen to powder, mix the two ingredients together, and let them remain untouched for three days. In the mean time dissolve 20lbs. of molasses in water, boil a peck of gramm (a kind of pea), to a jelly, boil a peck of mirabolans also to a jelly, mix the three liquors, and incorporate part of the mixture very accurately with the lime and sand, so as to make a very fluid cement: some short tow is now to be beaten very well into it, and it is then fit for use. The bricks are to be bedded in as thin a layer as possible of this mortar; and, when the workmen leave off, though but for an hour, the part where they recommence working is to be well moistened with some of the above liquor, before the application of any fresh mortar. When this is used for stucco, the white of four or five eggs, four ounces of butter or sesamum oil, and a pint of butter-milk, are to be mixed up with every half bushel of cement, and the composition is to be applied immediately.

It is to be regretted, that no experiments have been instituted to ascertain the cause of the induration of calcareous cements. It is attributed by Dr. Higgins to the absorption of carbonic acid; but several circumstances contradict this supposition. In numerous instances the cement hardens long before the lime is saturated: in the different kinds of maltha the lime combines with the albumen, mucilage and oil with which it is in contact, and in all probability takes up little or no carbonic acid; and, if it be true, that the lime in old mortar cannot by burning be re-converted into quick lime, this would imply a chemical union of the ingredients; and it may reasonably be questioned whether, even in the simple calcareous cements, carbonic acid acts so important a part as is usually attributed to it.

Chaff-Cutter

Chaff-*Cutter*, in *Rural Economy*, an implement conſtructed for the purpoſe of cutting hay, ſtraw, and other ſubſtances into chaff. Inſtruments of this ſort conſiſted formerly ſimply of a box and a cutting blade; but they are at preſent much improved, being made of different forms and conſtructions, ſo as to perform the work with greater economy and diſpatch. Mr. Cook has invented one, which, by means of a man and boy, will cut one hundred quarters a week; and when fixed to a large wheel, and turned by an animal, ſuch as a poney or aſs, will cut half the above quantity per day. Another contrived by Mr. Naiſer is capable of cutting three quarters an hour, by the aſſiſtance of two men, and coſts about ten guineas. An inſtrument for this purpoſe, made by Mr. James Pihe, is likewiſe both cheap and of the moſt ſimple conſtruction. It is fixed on a wooden frame, which is ſupported with four legs; and on this frame is a box for containing the ſtraw, four feet ſix inches long, and about ten inches broad: at one end are fixed acroſs the box two rollers, inlaid with iron, in a diagonal line, about an eighth of an inch above the ſurface; on the ends of theſe rollers are fixed two ſtrong braſs wheels, which take one into the other. On one of theſe wheels is a contract wheel, whoſe teeth take in a worm on a large arbour; on the end of the arbour is fixed a wooden wheel, two feet five inches diameter, and three inches thick. On the inner part of this wheel is fixed a knife, and at every revolution of the wheel the knife paſſes before the end of the box, and cuts the chaff, which is brought forward between the rollers, which are about two inches and a half aſunder. The ſtraw is brought on by the worm taking one tooth of the wheel every round of the knife: the ſtraw being ſo hard preſſed between the rollers, the knife cuts off the chaff with ſo great eaſe, that twenty-two buſhels can be cut within the hour, and makes no more noiſe than is cauſed by the knife paſſing through the chaff. It conſiſts of the box into which the ſtraw is put, and an upper roller, with diagonal projecting ribs of iron; the whole moving by the revolution of the braſs wheel, on the axis of which it is fixed. Another braſs wheel has upon it a face wheel, whoſe teeth take into the endleſs ſcrew on the arbour, while the teeth on the edge of this wheel enter between thoſe on the edge of the other wheel. On the axis of the latter braſs wheel is a roller with iron ribs, ſimilar to the above, but hid within the box. The arbour has one of the ends of which it is compoſed made ſquare, and paſſing through a mortiſe in the center of the wooden wheel, which is faſtened by a ſtrong ſcrew and nut; the other end of this arbour moves round in a hole within the wooden block; and the knife is made faſt by ſcrews to the wooden wheel, and kept at the diſtance of nearly three quarters of an inch from it, by means of a ſtrip of wood of that thickneſs, of the form of the blade, and reaching to within an inch of the edge. The handle is mortiſed into the outſide of the wooden wheel.

An improved machine of this ſort has been invented by Mr. Robert Salmon, of Woburn, Bedfordſhire, and deſcribed in the Tranſactions of the Society for the Encouragement of Arts, &c. With it the chaff is cut by two knives, fixed on the inſide of the fellies to two wheels, which are ſtrongly connected together; the edge of the knives being at an angle of about forty-five degrees from the plane of the wheel's motion. Theſe knives are ſo fixed as to be forced forward by ſprings on the wheel, which ſprings are formed to adjuſt, and act more or leſs, as occaſion may require, ſo as to give the knives as much preſſure againſt the box as may be requiſite to cut the ſtraw. The knives are prevented from coming too forward, and occaſioning unneceſſary friction, by wedges being put in under the ſtaples; which wedges, as the knives wear, muſt be drawn out ſo as to admit the knives to come more forward. With the before-mentioned proviſions, it will be found very eaſy at any time to put on new knives, as the ſprings, &c. will always adjuſt them to their work.

On one ſide of the wheel is fixed a round block of wood, in which there are four holes and a moveable ſcrew; to this block is ſcrewed one end of the feeding-arm, running nearly horizontally to the croſs bar at the end of the box; to which croſs bar there is a pin, moveable to five different holes, by means of which, and the four holes in the block before deſcribed, twenty changes in the length of the chaff may be obtained. The ſtraw is brought forward by the rollers in the box, the form of which has been juſt deſcribed, which rollers are turned from the outſide by the triggers or ratchet-wheels on each ſide of the box, which move more or leſs, according to the ſtroke given to the croſs bar by the feeding-arm and wheel. By this mode of feeding, the ſtraw is per-

fectly at reft, and does not prefs forward at the time of the knife cutting; and, by means of the pins being taken out of the crofs-bar, the feeding is inftantly thrown off, although the wheel and knives may continue their motion. Under the box is fufpended the preffing weight, which may be made more or lefs powerful by fhifting the weight on the bearer to which it hangs, and alfo may be thrown on either fide, more or lefs, as occafion may require; which will be found ufeful, in order to force the ftraw towards the knife, and to counterbalance the ratchet-wheel of the upper roller. Near the fulcrum of this bearer is fixed a chain, the upper end of which is fufpended from a roller; at each extremity of which is a fmall bar of iron, joined to the end of the upper fpiked roller, by which means the ftraw is always equally preffed in paffing the two-fpiked rollers. The winch by which the machine is turned is of the common kind, and the frame of the machine is to be made very firm and ftrong.

In order to apply this implement to the beft advantage, the inventor propofes a fecond box, to be placed at the end of the firft; which box may be of any length, and fufpended by a line and counter-weight, whereby the end of it is brought down level whilft filling with ftraw, and then drawn up, fo as to give the box a declivity, to make the ftraw more eafily come forward.

It is fuppofed that much advantage may be derived in this inftrument from its cutting various lengths, refting during the cut, the knives being adjufted to their work by regulating fprings, the feeding being readily thrown off, and the preffure moveable to either fide. It is alfo well calculated to be applied to any power which may be occafionally fixed to the oppofite fide to that on which it is turned by hand; and, by the additional box, when ufed by hand, the workman will be enabled to cut for fome continuance, without ftopping to feed.

Where threfhing machines are in ufe, thefe implements may frequently be attached to them with great advantage. There are many other inftruments of this fort conftructed in different ways; but thofe which are the leaft complex, and can be afforded at the cheapeft rate, are the moft adapted to the purpofe of the farmer. See CUTTING-BOX.

The above machine, as confiderably altered and improved by Mr. Rawntree, is seen in *Plate* VII. on *Agriculture*, in which *fig.* 1. is a fide, and *fig.* 2. an end view of it. The advantages of this implement are, 1ft, Its great fimplicity; 2d Its cutting the chaff of various lengths; 3d, The ftraw being at reft while the knives are making the cut; 4th, The friction being lefs, more work of courfe may be done with equal labour.

A, is the handle.

B, B, the fly-wheels on which the knives are fixed.

C, the ratchet-wheels, and rollers for drawing the ftraw forwards.

D, the rods to work the ratchet-wheels, connected with the lever and crank.

E, the box for containing the ftraw.

F, the lever and weight for preffing the ftraw.

G, the knives.

H, the crank for regulating the cut.

I, the frame.

At *fig.* 3. is reprefented Mr. M'Dougall's patent chaff-cutter, which is a very ufeful inftrument of this kind. In this machine the inventor has been particularly careful fo to conftruct it, that, in cafe it fhould be accidentally broken, it might be eafily repaired by any common mechanic. The fubftance to be cut into chaff may be preffed as hard as the workman choofes, by fimply placing the weight near to the end of the lever. But the chief excellence of the inftrument confifts in the inventor having judicioufly applied a fpiral groove in the room of the endlefs fcrew, commonly ufed by other agricultural inftrument-makers, by means of which he has in a great degree got rid of friction; and the lever may rife to any height, without putting the machine out of work.

It has been remarked by Mr. Young, that the number of machines which have been invented of late years for this purpofe, moft of which perform their work with fufficient accuracy, leaves no farmer in the kingdom under the neceffity of employing the common chaff-box, which is worked by thofe only who have acquired the art of making ufe of it, and who commonly make much greater wages per day than the ordinary pay. He obferves that there is a very good machine of this fort made at Thetford, which only cofts eight guineas. It has been obferved by a late practical writer, that as the principal objects aimed at in the conftruction of thefe machines are thofe of expedition and the leffening of manual labour, it is evident that many of thofe of the improved kind muft anfwer fuch purpofes much more effectually than fuch as were formerly in ufe, efpecially where they are attached to any great power, fuch as that of horfes, water, &c. as in the cafe of threfhing machines, or other mills, to which they are in general well fuited, as has been noticed above.

Mr. Page of Cobham has, according to Mr. Young, at the trifling expence of only five pounds, added a mill-wheel to his chaff-cutter, by which means a boy and a little poney cut twenty bufhels of chaff per hour.

Chalk

CHALK. The colour of this mineral is yellowifh white, more rarely fnow-white, or greyifh white: when contaminated with iron it has more or lefs of an ochery tinge. It occurs generally in mafs, fometimes diffeminated, or invefting other minerals. It is without luftre, is opaque, has a fine earthy fracture, and breaks into blunt-edged angular fragments. It ftains the fingers, gives a white ftreak, and, when pure, is very foft, and almoft friable. It has a meagre feel, and adheres to the tongue. Sp. gr. 2.3. It effervefces violently with acids. When mixed with iron it is both harder and heavier.

In a ftate of purity, chalk appears to be compofed only of water, lime, and carbonic acid; but Mr. Kirwan obtained from the analyfis of a fpecimen,

53	Lime
42	Carbonic acid
3	Water
2	Alumine
100	

Chalk, confidered geologically, is among the moft recent in formation of the feveral varieties of carbonat of lime. It occurs in thick beds nearly horizontal, alternating with thin layers of flint nodules, and with the fame irregularly difperfed through its fubftance. It contains in abundance the relics of marine organized bodies, fuch as echinites, gloffopetræ, pectinites, &c.; and alfo, not unfrequently, the hard parts of amphibious and land animals, fuch as the heads and vertebræ of crocodiles, and teeth of elephants.

Beds of chalk are of frequent occurrence in the eaft and fouth parts of England, alfo in the north eaft of France. Chalk is alfo met with in fome of the Danifh iflands in the Baltic, and in Poland.

The ufes of chalk are very great. The more compact varieties are employed as building-ftone, and are burnt to quicklime: it is alfo largely ufed in polifhing metals and glafs, in conftructing moulds to caft metals in; by carpenters and others as a material to work with, and by ftarchmakers and chemifts to dry precipitates on.

CHALK, in *Agriculture*, is a calcareous fubftance, which, when pure, is of a white colour, moderate confiftence, and dufty furface; ftains the fingers; adheres flightly to the tongue; does not harden when heated, but, on the contrary, in a ftrong heat burns to lime, and lofes about fourtenths of its weight. It effervefces with acids, and diffolves almoft entirely in them. It may alfo be added, that this folution is not difturbed by cauftic volatile alkali, as this is a circumftance that diftinguifhes it from magnefia. It has the property of promoting putrefaction. In its native ftate it is ufeful as a manure, upon the fame principle as limeftone; but it is more eafily pulverized, and lighter, or more porous in its nature. Nearly the whole of this material is calcareous earth, whereas none of the marles contain more than a fourth part of that fubftance. It is in high efteem in the more fouthern counties of England, where it abounds very much. Its beft effects are produced upon deep foils which contain no calcareous earth. It is obferved to have but very little effect upon lands where the fubftratum is chalk; and if the foil be thin, it does mifchief in fuch cafes. When ufed upon light thin foils, it is moftly made into compofts with earth and dung, or fome other fimilar material. When thefe are well mixed together, and duly proportioned, they produce valuable crops; and their influence is faid to continue many years, in fuch inftances.

The common method of ufing this fort of compoft is either by laying it upon fallows for wheat, and mixing it intimately with the foil by ploughing and harrowing, or upon grafs as a top-dreffing: in both cafes it has been found to anfwer well; and in the latter it is found capable of deftroying mofs, rufhes, and all coarfe aquatic plants that grow

in heavy, four, or wet lands; while, in the former, it opens and pulverizes the foil, and never fails to produce good crops of that grain, or other kinds.

In making ufe of it, it has been recommended that it fhould be broken as fmall as poffible. It fhould be dug from the pit near the end of autumn, and be laid on the land immediately; as at that feafon the air is generally moift, the moifture will of courfe be abforbed by the chalk. This will occafion it to fwell, and break down into pieces; and if froft fhould come on, it will much accelerate the bufinefs: but when it is dug in fummer, it lofes its moifture, and acquires a hardnefs, which in a great meafure prevents it from being of any ufe. It fhould in no cafe be ploughed in till its parts are properly broken down and feparated, and then it fhould be completely harrowed in and mixed well with the foil, or mould of the land.

If the foil be thin and light, a certain proportion of dung will, it is faid, be ufeful; but if it be heavy, the dung is afferted to leffen the operation of the chalk. It is generally thought that lands which have been completely chalked will not bear a repetition of it for fome time. A compoft of it, however, may be ufed to great advantage. In the fouthern counties a field has been, it is obferved, chalked, and dreffed with chalk and dung mixed, in portions alternately; and the former has been found to produce very bad crops, but the latter very good ones. It is afferted, that laid on beyond a certain quantity, it will not only ceafe to operate as a manure, but even prove hurtful to the land. It ought, therefore, to be ufed with caution, and due pains be taken not only to afcertain the ftrength of the chalk, but the quality of the foil on which it is to be laid, before the application is made.

But there can be no doubt that chalk is a lafting manure, when applied on fuitable foils; which are thofe of a cold, four nature, fuch as ftiff untractable clays. Pliny has remarked that it was the cuftom of the ancient Britons to chalk their lands, by which they received a great and lafting improvement in the fertility of them.

In regard to the different kinds of chalk which fhould be diftinguifhed by the farmer, the hard, dry, and firm fort is much the fitteft for burning into lime; but that of the fat and unctuous kind by far the beft to be ufed in the crude ftate.

It has been ftated that in fome parts of Effex they lay from five to eight waggon loads of chalk on an acre, either upon a clover lay while feeding, or on a fummer fallow; and that the effect of a very thin dreffing of it is feen immediately to an inch, like that of rotten dung, and lafts twenty years, fifteen in good heart. The foil is a loam; they have alfo a little clay, and no fand: on gravels the effect is but flight. They bring the chalk from Malden, whither it is brought by fea from Kent, and a waggon load cofts moftly ten fhillings at the quay. It is rather hard; the fharpeft frofts leave many lumps unbroken; thefe they break with pick-axes. The effervefcence with vinegar is pretty confiderable, but in water it fcarcely falls at all. It is alfo a general opinion in that county, that land which has been once chalked will not take it again; they acknowledge, however, that when mixed with earth and dung it is then excellent. They obferve, that laying a flight dreffing of chalk and earth, or dung, on a field never chalked, will take fo much effect, that the fame field will not anfwer to chalk completely. They obferve alfo, that the chalk prefently gives the land a red colour. And they are of opinion, that chalk is a great enemy to good grafs; and affirm, that a field which, before chalking, will run of itfelf to a fine head of white clover, no longer does it after chalking. There is no faying any thing againft experience: we fhould not, however, draw general conclufions from partial experiments. Much of the effect of manures depends upon the foil on which they are laid. About Enfield, as obferved in a paper in the Annals of Agriculture, the fame chalk does wonders, which at North Mims has very little effect: the one is a rich loam, the other a poor gravel. And near Sandwich, in Kent, chalk has been found in a very high degree to improve a fandy foil, giving it tenacity, and totally exterminating that pernicious weed the corn marigold, which is provincially called *yellow bottle*, *buddle*, or *golds*, and fo abundant in fandy foils. They lay on forty loads of forty bufhels each to an acre. Upon pafture land they think it does nothing. In Hertfordfhire it is thought that chalk makes the land plough much better, and renders all manures much more effectual. If a field be divided into parts, one chalked, a fecond chalked and manured with dung or foot, afhes, &c. and a third dunged or afhed without chalk; although chalk alone has no effect, yet the other manure on the chalked part will have a much greater effect than on the part where no chalk is laid. Facts of this fort are highly interefting, but want to be more correctly made.

It has been remarked by the author of the Synopfis of Hufbandry, who has had much experience in a diftrict where it abounds, that this manure, though it falls infinitely fhort of marl in its fertilizing quality, is neverthelefs poffeffed of virtues which defervedly entitle it to the efteem of the farmer. By a proper application of this fubftance, the moft tenacious clays are, he fays, rendered friable and mellow; and thus, their native ftubbornnefs and adhefion being overcome, the feveral particles of the foil are enabled to imbibe the full benefit of the different changes of the atmofphere; and hence they are brought to work kindly under the feveral operations of the plough, harrow, &c. and to produce ample crops of grafs or corn, which, before the application of this manure, they were incapable of bringing to perfection. So great are the benefits accruing from this manure, when laid on a ftiff clayey foil, that the Effex farmers find their account in freighting barges from the chalk cliffs in Kent, and afterwards carrying it with their teams feveral miles up the country; all which, though attended with a heavy expence, is found to anfwer the purpofe extremely well, as it would, he think, be impoffible to reduce thefe ftubborn clays to a proper tilth without the previous application of this manure. Nor is it on clays only where chalk may be laid to advantage: gravels, efpecially thofe which lie near the fprings, and all wet foils, may, he fuppofes, be dreffed with this manure, which will never fail to meliorate and fweeten the ground, and enable it to retain longer the virtues of the dung that may be applied, which, on thefe hungry foils, is liable to difappear in a fhort time: nay, fo partial are fome farmers to the ufe of this manure, that he has known it carried on foils where the chalk lay within a few inches of the furface.

It has been ftated, that the action of chalk on the foil is either chemical or mechanical. It acts chemically as an abforbent, contributing to preferve dry thofe lands which are poachy and wet; and by its attraction for acids it may haften the putrefaction of vegetables. It acts mechanically, by entering into the compofition, and totally altering the nature of clay, converting it by proper pulverization into a fpecies of marl. By infinuating itfelf between the particles of clay, it deftroys their adhefion; thus preventing it from becoming too hard in fummer, and too wet in the winter feafon.

It is obferved by Mr. Bannifter that there are two methods of obtaining chalk. The firft is by uncallowing a piece of

ground, and making it convenient for a pit, where the carts may be drawn into it, and filled: this is on a presumption that the chalk lies near the surface, and that the pit is within a small distance of the field on which the manure is to be laid. The other method is to sink pits in the field where the chalk is intended to be laid as a manure, and which, in his opinion, is far preferable to that of drawing it in carts as before mentioned. In this case, a number of pits are to be sunk according to the extent of the field. These pits are to be made in the form and circumference of a well, with an apparatus at the top, and a bucket to draw up the chalk. The people who undertake this business, having been brought up to it from their infancy, perform it, he says, with great facility, and without any timidity, though attended with much danger. A person is employed at the top to draw up the contents of the pit, shoot the chalk into the cart, and wheel the same on the land. When the labourer has arrived at the chalk, which takes up a longer or less interval of time according to the depth at which it lies, and has dug some little time therein in the perpendicular form wherein he began the pit, he proceeds to form apertures in different horizontal directions; so that where the chalk is good, and the pit stands firm, large tracts of ground are undermined for this purpose. The price for digging chalk is, he says, 1s. per foot till the chalk be found, after which for the chalk 1s. per load, which is twelve baskets; and a penny per load for wheeling the chalk on the land, the farmer providing a horse and cart for that purpose. The quantity usually laid on an acre is from eighty to a hundred loads.

From this description of chalk drawing, he says, "it is evident that much care and circumspection are required to prevent any deceit being imposed on the farmer by the workmen, to which their eagerness of acquiring large wages will be a powerful inducement."

He adds, that "the best chalk is that which is white and hard; and the deeper it lies beneath the surface, the more efficacious is the dressing supposed to be, as partaking less of the nature of the soil whereon it is to be applied as a manure; indeed on a clayey soil it is seldom to be met with, but at a considerable distance beneath the surface of the field. The most eligible season, he says, for the performance of this work is in the early part of the winter, as the chalk which is laid out at that season will, by aid of the succeeding frosts, be, in a great measure, meliorated and reduced to crumbs at the time of fallowing in April; whereas, should the business be deferred till the spring, no inconsiderable portion of the chalk will remain in lumps till the next winter. From this neglect, a twelvemonth will be lost in point of time, as this manure will lie on the ground without answering any good purpose till the lumps shall have been slacked by moisture and frosts; and that chalk is always most highly esteemed which yields soonest to the effect of the weather in falling into crumbs. This manure may be laid on the ground in the summer, without any other inconvenience than what has been before mentioned; contrary to the opinion of some people, who think that such chalk, having remained on the surface during the summer months without ruming, will, on that account, be less susceptible of the frosts in the succeeding winter: but this idea is erroneous; and as it may often suit the economy of the farmer to lay this chalk out in the summer, either from a neighbouring draw-pit, having at that time little other employment for two men and horses, or if he may be inclined to sink a pit in the field at that time; in either of these contingencies, the business may, he thinks, be safely ventured upon in that season; and it would be far better to suffer the ground, which is thus summer chalked, to lie unploughed till the succeeding spring, than to crop it with wheat at the autumn after the manure is applied; for, having enjoyed the benefit of the frosts in the following winter, the ground will come in properly for a wheat season in the next year: and this may be generally effected, he says, where a person is inclined to lay on his chalk in the summer. For instance, suppose a lay ground be intended for a fallow the next year, this may be chalked in the summer time, with very little inconvenience or injury to the farmer, as the grass which would have been produced from it between midsummer and the following spring could have turned to little account."

It is conceived by the same writer, "that when land is dressed with chalk, the surface ought to be pretty thickly covered over, otherwise it will fail to answer the end of pulverization, in which consists the chief virtue of this manure: and though the expence of chalking may appear considerable to those who are unacquainted with its effects, the good consequences accruing to the future crops will be found in the end amply to compensate the primary charges, and from whatever cause this improvement arises, whether an immediate fertility be conveyed to the soil by the chalk, or whether this dressing acts on the soil by destroying its adhesion, and thus disposes it to work more kindly, and to part with its vegetative particles, which were before so closely united as not to be drawn forth by any other means: in whichever of these ways the chalk acts upon the land it matters, he thinks, very little to the farmer, so that the intention be accomplished, namely, the acquisition of a more abundant crop. For his own part, he is inclined to think that the chief virtue of the chalk resides in its power of correcting the adhesion of stiff soils, and in its meliorating quality, and that it is much inferior to dung, in point of accelerating the growth of the crop; so that where a field has been well dressed with this manure, which is said to be of so lasting a nature as to shew its good effects at the distance of twenty years, it is by no means to be understood, that this field is not to be dunged, or to have any further addition of manure during this interval: on the contrary, such ground ought never to lose its turn of the dung-cart; and, indeed, on farms of a clayey soil, those fields only can be dunged to advantage which have been previously chalked; for experience hath demonstrated, that, without the application of this manure, dung will be of but small avail on these stiff soils."

It is remarked further by the same practical writer, "that on gravelly soils, where the springs lie within a small distance of the surface, it often happens that the water flows in before the chalk is found, and thus all further endeavours at that spot are rendered abortive, and another pit must be sunk in a different part of the field. Obstacles to this work sometimes, he says, fall out from the light contexture of the soil, which does not unfrequently give way to the destruction of the chalk-drawer. To the farmer, it may be of some consequence to consider the nature of his land, ere he embarks in this scheme of husbandry; as, if from circumstances above-mentioned, he may have reason to think that his pit will not stand firm, it would be a matter of prudence to desist from any further thoughts of sinking a perpendicular pit, and change the mode of operation, by bringing his chalk from an uncallowed pit: but where it can be obtained at a moderate expence, and with a tolerable certainty of success, the preceding method is, he thinks, certainly the most eligible." See CALCAREOUS *Earth*, and MANURE.

In the chalking of land, the method pursued in Herefordshire, where the persons employed in it follow it as a trade, is the following, according to Mr. Walker: "a spot is fixed upon, nearly central to about six acres of land,

to be chalked. Here a pit, about four feet in diameter, is sunk to the chalk, if found within twenty feet from the surface; if not, the chalkers consider that they are on an earth pillar, fill up the pit, and sink in fresh places, till their labour is attended with better success. The pit from the surface to the chalk is kept from falling in by a sort of basket-work, made with hazel or willow rods and brushwood, cut green and manufactured with the small boughs and leaves remaining thereon, to make the basket-work the closer. The earth and chalk are raised from the pit by a *jack-rowl* on a frame, generally of very simple and rude construction. To one end of the rowl is fixed a cart wheel, which answers the double purpose of a fly and a stop. An inch rope of sufficient length is wound round the rowl, to one end of which is fixed a weight, which nearly counterbalances the empty basket fastened to the other end. This apology for an *axis in peritrochio*, two wheelbarrows, a spade, a shovel, and a pick-axe are all the necessary implements in the trade of a company of chalkers, generally three in number. The pit-man digs the chalk and fills the basket, and his companions alternately wind it up and wheel its contents upon the land; when the basket is wound up to the top of the pit, to stop its descent till emptied, the point of a wooden peg, of sufficient length and strength, is thrust by the perpendicular spoke in the wheel into a hole made in the adjoining upright standard of the frame to receive it. The pit is sunk from 20 to 30 feet deep, and then chambered at the bottom; that is, the pit-man digs or ruts out the chalk horizontally, in three separate directions; the horizontal apertures being of sufficient height and width to admit of the pit-man's working in them with ease and safety. One pit will chalk six acres, laying 60 loads on an acre. If more be laid on, and to the full extent of chalking, viz. 100 loads, then a proportionable less extent of land than six acres is chalked from one pit. Eighteen barrow-fulls make a load, and the usual price for chalking is 7d. per load, all expences included; therefore the expence of chalking at 60 loads per acre is 1l. 12s. 6d.; and at 100 ditto, 2l. 18s. 4d. As the chalk is considered to be better the deeper it lies, and the top chalk, particularly if it be within three or four feet from the surface, very indifferent, and only fit for lime, or to be laid on roads, gateways, &c. the chalkers must be directed to lay by the chalk for the first three or four feet in depth, to be applied to the above purposes; or, if not wanted, to be again thrown into the pit when filled up; and also to pick out the flints from the chalk before it is carried on the land, for, if they are not narrowly watched, they will chalk with both."

It is added, that "Mr. John Hill of Coddicott farms upwards of 1200 acres in the adjoining parishes of Coddicott and Kimpton, a considerable part of which is his own estate. He has chalked many acres of land, and approves much of the practice. He chalked a field of strong clay land in the autumn of 1793, laid on sixty loads to an acre, and the chalk where the pits were sunk lay about ten feet from the surface. Mr. Walker viewed the field the 7th of August 1794; it had borne a crop of peas since it was chalked, and was then under the plough, preparatory for a crop of wheat. The chalk was good, and the land appeared to work well, though the chalk was not then thoroughly incorporated with the soil. Mr. Hill never lays more than 60 loads of chalk on an acre; this he finds will not only make the land work much better, with less strength of cattle, but also, with a light coat of dung, or spring dressings occasionally laid on to quicken the vegetation, produce abundant crops for ten years; he then chalks again with equal success."

This sort of work should proceed with dispatch during the summer months in *all* cases, and in the autumnal ones in many situations where there is no danger of poaching the ground. Mr. Young suggests, that much advantage may be derived, in performing this sort of business, from the use of small three-wheeled carts, as the third wheel affords a support for the cart and load while filling, without the fill horse, and of course one horse may be sufficient for two carts, one being discharged upon the land while the other is loading. See MANURE.

CHALK, *black*. See SLATE.

CHALK, *brown*. See TRIPOLI.

CHALK, *French*. See STEATITE.

CHALK, *fungous*. See AGARIC *mineral*.

CHALK, *red*. See *Ores of* IRON.

CHALK, *silver*. See AGARIC *mineral* and ARGENTARIA *creta*.

CHALK, *Spanish*. See STEATITE.

CHALK, *yellow*. See TRIPOLI.

CHALK-*drawings*. See DRAWING and ENGRAVING.

Charcoal

CHARCOAL, in *Chemiſtry*. Under the article CARBON are mentioned the chemical properties of charcoal; nothing further therefore remains to be deſcribed except the method of preparing the ſubſtance and a few other particulars intimately dependent upon it.

Charcoal is prepared either by burning or diſtillation; of theſe the firſt is the ſimpleſt, moſt ancient, and uſual method, on which account we ſhall begin with it.

The buſineſs of charcoal burning takes place during the whole of the ſummer months, and is for the moſt part carried on in the woods to ſave the expence of carriage. Two or three families commonly unite for this purpoſe, dwelling in tents or temporary huts during the time in which they are thus employed for the convenience of being near their buſineſs. After they have felled the timber, and it is become ſufficiently dry, the proceſs of converting it into charcoal is begun by raiſing a plot of ground a little higher than the ſurrounding ſurface, and bringing it to a ſlightly convex form by beating it, and thus forming a hard, dry, and ſolid floor. In the center of this area is placed a circle of ſticks adjoining each other and compoſing a vertical hollow cylinder from three to four inches in diameter, and about ſix feet high. Round this interior cylinder are ranged ſucceſſive concentric circles formed by truncheons from one to ten inches in diameter, care being taken that the truncheons in any one circle are of the ſame diameter, and that one built of the largeſt wood be always ſucceeded by one of the ſmalleſt wood, in order that there may be as few interſtices as poſſible. The outermoſt circle is compoſed of bruſh-wood. When the pile meaſures from twenty to thirty feet in diameter, it is ſufficiently large; a coating is now laid on of turf, the graſſy ſide next to the wood, and dry earth is heaped up round the bottom of the pile, and well rammed in order to prevent the admiſſion of air. Three or four ſcreens formed of large hurdles well ſtuffed with bruſhwood, are alſo prepared in order to protect the pile from the violence of the wind. All the preparations being now completed, the pile is kindled by dropping lighted chips down the hollow cylinder in the center, which, in proportion as they are conſumed, are ſupplied by others during the firſt three or four days, at the end of which period, the kindling of the pile is completed. The top of the cylinder is now cloſed, and a row of holes, each about two inches in diameter, is pierced at the baſe of the pile, by which the requiſite quantity of air is ſupplied, and a paſſage is afforded for the ſmoke and vapours. When the ſmoke nearly ceaſes to iſſue from theſe holes, a ſecond row is opened, about ſix or eight inches above the firſt, which are now cloſed; in this manner the fire is conducted to the top of the pile in about a fortnight; at which time the pile is covered up with earth as accurately as poſſible, till the fire is completely extinguiſhed. Thoſe pieces that are found not to be ſufficiently charred are called *brands*, and are employed as fuel for the next fire.

Although charcoal prepared by the above method is fully adequate to all the purpoſes of fuel to which this ſubſtance is applied, yet in the manufacture of gunpowder, and for ſome other uſes, it is of eſſential importance to procure a charcoal of greater purity than common. This was formerly done by ſelecting the ſtems of willow, alder, and ſome other of the aquatic trees, and charring them in the uſual manner, but with peculiar care. Of late, however, a conſiderable improvement in the preparation of the finer charcoal has taken place, by charring or diſtilling the wood in cloſed iron cylinders. For this purpoſe a large cylinder of caſt iron fixed in maſonry over a grate, and furniſhed at one end with a door capable of being accurately cloſed, and terminating at the other in a curved pipe, is filled with the chips of any kind of wood; the door being then cloſed, and a fire lighted in the grate, the empyreumatic acid and all the other volatile parts of the wood are driven off by the heat, which is increaſed till the contents of the cylinder are red hot. The fire is then withdrawn, the cylinder is allowed to cool, and a black ſhining and remarkably pure charcoal (in greater proportion alſo to the quantity of wood employed than by the uſual way) is procured, admirably fitted for the uſe of the gunpowder-makers, and apparently poſſeſſed of the ſame qualities from whatever kind of wood it is made.

The proportion of charcoal yielded by particular woods is liable to be ſo materially affected by the age, and the dryneſs of the wood, as to render it almoſt impoſſible to obtain any correct reſult in the great way. The following table, from experiments in the ſmall way by Mr. Muſhet, will, however, be found to be intereſting, as all the woods before being charred were thoroughly dried and prepared, as nearly as poſſible in the ſame circumſtances.

100 Parts of	Lignum vitæ afforded	26.0	of Charcoal	of a greyiſh colour reſembling coak
	Mahogany	25.4		tinged with brown, ſpongy and porous
	Laburnum	24.5		velvet black, compact, very hard
	Cheſnut	23.2		gloſſy black, compact, firm
	Oak	22.6		black, cloſe, very firm
	Holly	19.9		dull-black, looſe and bulky
	Sycamore	19.7		fine black, bulky, moderately firm
	Walnut	20.6		dull black, cloſe, firm
	Beech	19.9		dull black, ſpongy, firm
	Norway pine	19.2		ſhining black, bulky, very ſoft
	Elm	19.5		fine black, moderately firm
	Sallow	18.4		velvet black, bulky, looſe and ſoft
	Aſh	17.9		ſhining black, ſpungy, firm
	Birch	17.4		velvet black, bulky, firm
	Scottiſh pine	16.4		tinged with brown, moderately firm

The author of the Rural Economy of the midland counties obferves, that in making charcoal, men accuftomed to the bufinefs cut and cord in wood in the winter, and burn during the fummer feafon. The minutiæ of the procefs of which are there, he fays, thefe. The fite, or hearth, being determined upon, the fward is pared off, and the fods laid on one fide. The wood ufually about the cord is then laid in a ring, fomewhat wider than the intended hearth; beginning on the outer circumference of the ring with the fmalleft of the round-wood, laying the larger pieces of top-wood, and the cloven roots, or but-ends, towards the center. With thefe laft, fome of them nearly as large as bufhel-blocks, they begin to make their pile, leaving a kind of chimney in the middle, (a vertical aperture, from a foot to eighteen inches wide), and round this core of roots fet up the top-wood, (which has previoufly been cut at the time of cording, in fuch a manner, that no forkednefs or other awkward crookedneffes are left; or, if not cut in this manner, or cut improperly, it is prepared by the colliers themfelves, previous to laying it ready for fetting), joining the blocks, or rather fitting them in, as clofe to each other as poffible; placing the convex fide of the logs outward, forming the pile in the fhape of an inverted bowl, nearly femiglobular. The pile being formed, it is covered over with fods, which are pointed, to keep in the heat the better, and the feams are filled up with fine pulverifed mould. The chimney is now filled with fhort pieces of dry wood; near the top a live coal is put; over this one layer more of dry pieces; and upon thefe a clofe cap of fod is placed: neverthelefs, this one coal, not larger than the fift, and excluded from the open air, is fufficient to fet the whole pile on fire. As the pieces in the chimney burn away, they are replaced by frefh ones: thus feeding the fire with frefh fuel. Paled hurdles are placed on the windward fide of the heap, to prevent the fire from acting partially.

When the fire begins to work itfelf out, at the outward fkirts of the bottom of the pile, it is known that the coal is fully burnt, (or rather the wood fufficiently charred), which it will be, in a pile of ten cord, in fine dry weather, in feven or eight days. The fire, during the whole time, is carefully kept from breaking out, by throwing mould or afhes upon the weak parts: fo that, though the fire paffes through every part of the wood, little or none of the matter of heat efcapes. It is obfervable, he fays, that notwithftanding the intenfe heat, no part feems to be confumed; not the bark only, but even the mofs upon it, comes out as entire as when it went in: the only apparent change is, in its being rendered friable and of a black colour. Wood that is charred, feems, he fays, to be only very highly dried. It fhrinks confiderably during the procefs of charring; but there is no vifible derangement of parts. One of the fmaller pieces, which is not broken in the drawing, appears as entire when it comes out as when it went into the pile. The brittlenefs after charring, however, fhows that the texture of the wood is altered by the action of the fire. As foon as the fire is out of the coal, on the outfide of the heap, the workmen begin to draw; which is done by running a peel between the coal and the hearth, raifing up the coal in fuch a manner as to let the mould and afhes of the fods fall through between the pieces, upon the inward parts, ftill full of fire. If this makes its appearance in any particular fpot, a peel full of afhes is immediately thrown againft it. Having got fufficiently near to the fire, the coals raifed by the peel are raked off with long, wide-toothed, iron rakes; the teeth about a foot long, and ftanding about fix inches a-part; the handle and head of wood, except a plate of iron on the back, with which the fmall coal is gathered together. No fieve, nor any rake with finer teeth than the above, is ufed. The coal being light, it is readily brought to the furface of the afhes and dirt; and, when there, is eafily collected with the back of the rake. The fide, thus drawn, being rounded up and fecured with afhes, another, the cooleft part, is drawn in the fame manner. The drawing is an infernal bufinefs: the men working among fire and heat enough to fuffocate Satan himfelf. Such pieces as ftill retain fire, after they are drawn, are quenched with water; which the workmen have in plenty ftanding by them, in pails. If a large piece contain much fire, (which hides itfelf chiefly in the chinks of the large pieces), it is plunged bodily into the water. If the heap itfelf prove too refractory to be kept under by the afhes alone, a fufficient quantity of water is thrown upon it, to keep the fire under. Such large pieces as are fufpicious are laid on one fide, in order that thofe which take fire may be the more readily difcovered. A waggon attends to take away the coal as faft as it is drawn: for, if it take fire, or get wet in the hands of the burners, it is at their rifk; and, while in the waggon, it is at the rifk of the waggoner. Every particle burnt is fo much entire wafte.

The quantity of afhes arifing from a charcoal hearth, he fays, is confiderable. There were four cart loads taken up from two fmall hearths, and a load or two more ftill remained.

The duft of charcoal has been found, by repeated experience, to be of great benefit to land, efpecially to fuch foils as are ftiff and four. It is to be ufed in the fame manner as foot and wood-afhes. See ASHES and SOOT.

And the author quoted above obferves, that charcoal afhes are in good efteem in the midland diftricts as a manure, particularly for turnips, and for fining grafs land. They arife principally from the fods ufed in covering, but in part from the bits of coal which break off in raking it out of the afhes. There cannot be any doubt but that all the refufe of charred materials that become reduced into a powdery ftate during the procefs of drawing the coal, is highly beneficial, when applied on the more ftiff and heavy forts of land as a manure, as much advantage has been derived from it in the experience of different cultivators.

The microfcope difcovers a furprifing number of pores in charcoal: they are difpofed in order, and traverfe it lengthwife; fo that there is no piece of charcoal, how long foever, but may be eafily blown through. If a piece be broken pretty fhort, it may be feen through with a microfcope. In a range the eighteenth part of an inch long, Dr. Hook reckoned one hundred and fifty pores; whence he concludes, that in a charcoal of an inch diameter, there are no lefs than five millions feven hundred and twenty-four thoufand pores.

It is to this prodigious number of pores that the blacknefs of charcoal is owing: for the rays of light, ftriking on the charcoal, are received and abforbed in its pores, inftead of being reflected; whence the body muft of neceffity appear black, blacknefs in a body being no more than a want of reflection.

Mathematical inftrument makers, engravers, &c. find charcoal of great ufe to polifh their brafs and copper plates, after they have been rubbed clean with powdered pumice-ftone. Mr. Boyle fays, that the more curious burn it a fecond time, and quench it in a convenient fluid. Plates of horn are polifhable the fame way, and a glofs may be afterwards given with tripoly.

Charcoal and foot-black are the two moft durable and ufeful blacks of the painter, and the varnifh-maker. Thofe of the former kind are ufed both as pigments and pencils; and charcoal crayons prepared from the willow are preferred on account of their foftnefs. See concerning them Lewis's Commercium Phil. Techn. p. 536.

Charcoal tinges glaſs in fuſion yellow, reddiſh, &c. and by baking ſtains it yellow. See ibid. p. 628. See alſo his obſervations on the differences of different charcoals, &c. and of the manner of diſtinguiſhing between the vegetable and animal, ibid. p. 336. and ſeq.

Charcoal was anciently uſed to diſtinguiſh the bounds of eſtates and inheritances; as being ſuppoſed incorruptible, when let very deep within the ground. In effect, it preſerves itſelf ſo long, that there are many pieces found entire in the ancient tombs of the northern nations.

M. Dodart ſays, there is ſometimes found charcoal made of corn, probably as old as the days of Cæſar: he adds, that it has kept ſo well, that the wheat may be ſtill diſtinguiſhed from the rye; which he looks on as a proof of its incorruptibility.

Chipping

CHIPPING, in the *Manufactures*, a term ufed by the potters and china-men to exprefs that common accident both of our own ftone and earthen ware, and the porcelain of China, the flying off of fmall pieces, or breaking at the edges. Our earthen wares are particularly fubject to this, and are always fpoiled by it before any other flaw appears in them. Our ftone wares efcape it better than thefe, but lefs than the porcelain of China, which is lefs fubject to it than any other manufacture in the world. The method by which the Chinefe defend their ware from this accident, is this: they carefully burn fome fmall bamboo canes to a fort of charcoal, which is very light, and very black; this they reduce to a fine powder, and then mix into a thin pafte, with fome of the varnifh which they ufe for their ware: they next take the veffels when dried, and not yet baked, to the wheel, and turning them foftly round, they, with a pencil dipt in this pafte, cover the whole circumference with a thin coat of it: after this, the veffel is again dried; and the border made with this pafte appears of a pale greyifh colour when it is thoroughly dry. They work on it afterwards in the common way, covering both this edge and the reft of the veffel with the common varnifh. When the whole is baked on, the colour given by the afhes difappears, and the edges are as white as any other part; only when the baking has not been fufficient, or the edges have not been covered with the fecond varnifhing, we fometimes find a dufky edge, as in fome of the ordinary thick tea-cups.

It may be a great advantage to our Englifh manufactures to attempt fomething of this kind. The willow is known to make a very light and black charcoal; but the elder, though a thing feldom ufed, greatly exceeds it. The young green fhoots of this fhrub, which are almoft all pith, make the lighteft and the blackeft of all charcoal; this readily mixes with any liquid, and might be eafily ufed in the fame way that the Chinefe ufe the charcoal of the bamboo cane, which is a light hollow vegetable, more refembling the elder fhoots than any other Englifh plant. It is no wonder that the fixed falt and oil contained in this charcoal fhould be able to penetrate the yet raw edges of the ware, and to give them in the fubfequent baking a fomewhat different degree of vitrification from the other parts of the veffel, which, though if given to the whole, it might take off from the true femivitrified ftate of that ware; yet at the edges is not to be regarded, and only ferves to defend them from common accidents, and keep them entire.

The Chinefe ufe two cautions in this application: the firft in the preparation; the fecond in the laying of it on. They prepare the bamboo canes for burning into charcoal, by peeling off the rind. This might eafily be done with our elder fhoots, which are fo fucculent, that the bark ftrips off with a touch. The Chinefe fay that if this is not done with their bamboo, the edges touched with the pafte will burft in the baking: this does not feem indeed very probable; but the charcoal will certainly be lighter made from the peeled fticks, and this is a known advantage. The other caution is, never to touch the veffel with hands that have any greafy or fatty fubftance about them; for if this is done, they always find the veffel crack in that place. Obf. fur les Cout. de l'Afie.

Clay

CLAY. In common language, any earth which poſſeſſes ſufficient ductility when kneaded up with water to be faſhioned like paſte by the hand, or the potter's lathe, is called a *clay*. In *Mineralogy*, however, the term has a ſomewhat more extended application, comprehending not only the proper ductile clays, but certain other mineral ſubſtances which bear a ſtrong analogy to them. They may be conveniently arranged under the five following ſub-ſpecies.

1. Subſp. *Pure clay.—Reinethon Erde*, Germ.—*Lac Lunæ* of ſome authors.

Its colour is ſnow-white or yellowiſh-white. It occurs in ſmall kidney-ſhaped pieces. It is without luſtre; its fracture is fine earthy; it is opake; ſtains the fingers ſlightly; adheres feebly to the tongue; is fine but meagre to the touch; is very light, ſoft, and eaſily frangible. Its component parts, according to a recent analyſis by Fourcroy, are,

45	alumine
24	ſulphated lime
27	water
4	lime and ſilex.
100	

It has hitherto been found only at Halle in Saxony, where it occurs very near the ſurface, and accompanied by gypſum.

2. Subſp. *Porcelain clay.—Porzellauerde*, Germ.

Its colour is reddiſh-white, paſſing to yellowiſh and greyiſh-white. It occurs in maſs and diſſeminated. It ſtains the fingers; is for the moſt part ſlightly coherent, paſſing into duſty; is fine but meagre to the touch; ſlightly adheres to the tongue, and is but of little ſpecific gravity.

A ſpecimen, analyſed by Vauquelin, afforded the following reſult:

55	ſilex
27	alumine
0.5	oxyd of iron
2	lime
14	water
98.5	

When perfectly pure, it is nearly, if not entirely, fuſible in the greateſt heat of a porcelain furnace.

It forms beds in geiſs, and not unfrequently occurs in granite, occupying the place of the felſpar: indeed, it may readily be traced through various ſtates of induration into true felſpar; hence it has been conſidered by ſome as decompoſed felſpar, and by others as unformed or imperfect felſpar.

The clay employed in the manufacture of the Berlin porcelain, is procured from the diſtrict of Magdeburg: the beſt French porcelain clay (the ſubject of the above analyſis) is dug near Limoges; and the beſt Engliſh porcelain clay is procured from Cornwall: this latter is naturally mixed with quartz and mica, forming a granite, from both of which it is ſeparated by waſhing.

3. Subſp. *Common clay.—Potter's clay.—Pipe clay.*

Its colour is very various; when greyiſh-white it is called *pipe clay;* it alſo occurs greeniſh-grey, paſſing into verdegris-green; ſmoke-grey, paſſing into yellowiſh-brown; reddiſh-brown and browniſh-red; or, laſtly, bluiſh-grey, paſſing into blackiſh-blue. It occurs maſſive, or fine ſlaty, forming veins or beds; theſe latter, often of great extent and thickneſs. Its fracture is earthy, paſſing into uneven or imperfectly conchoidal. It is generally ſmooth, and ſomewhat unctuous to the touch; adheres pretty ſtrongly to the tongue, is ſoft and eaſily frangible.

When in veins, it generally occurs in primitive mountains, accompanying metallic ores; when in beds, it is uſually found in alluvial land, covered by or reſting on gravel.

It conſiſts eſſentially of alumine and ſilex, but generally contains, beſides, a variable proportion of oxyd of iron. Carbonated lime, too, is by no means an unfrequent ingredient, and when this abounds, the clay paſſes into marl. See Marl.

4. Subſp. *Indurated clay.—Clay-ſtone.*

Its colours are greeniſh-grey, bluiſh, aſh, ſmoke, and pearl-grey, or browniſh-red. It occurs in maſs; is opake and without luſtre. Its fracture is fine grained earthy, paſſing into ſlaty, ſplintering, and imperfectly conchoidal. It adheres but ſlightly to the tongue; is ſoft and eaſily frangible.

When put into water, it falls to pieces by degrees, but even then poſſeſſes very little ductility. It occurs in rock maſſes, in veins and beds, and forms the baſis of clay porphyry. It paſſes, on the one hand, into potter's clay, and, on the other, into jaſper.

5. Subſp. *Shale.*

Its colour is ſmoke-grey, yellowiſh, aſh, or bluiſh-grey, or greyiſh-black. It occurs in maſs. It is dull, but when mixed with mica is glimmering. Its fracture is ſlaty, approaching ſometimes to earthy. It is opake, ſoft, and eaſily frangible; it is meagre to the touch, adheres ſlightly to the tongue. Sp. gr. about 2.6.

It occurs in the independent coal formation, alſo in the moſt recent floetz trap and alluvial formations.

It generally breaks down when put into water, and by expoſure to the weather it decompoſes into a very unctuous and tenacious clay.

Of the above ſub-ſpecies, the firſt, on account of its rarity, is made no uſe of. The ſecond is the baſis of the European porcelains, for which it is well adapted, on account of its difficult fuſibility, and its hardneſs and compactneſs of texture when baked; it is even leſs fuſible than felſpar, from the decompoſition of which, in particular caſes, it certainly originates: but felſpar contains a very notable proportion of pot-aſh, which diſappears during its decompoſition, being probably waſhed away; and to this, no doubt, is owing the greater infuſibility of the clay.

The method of aſcertaining the goodneſs of porcelain clay is to knead it into a maſs with water, and after having dried it very gradually and thoroughly, to expoſe it to a full white heat in a muffle; if, after being thus baked, its colour is a pure white, if its texture is compact and porcellanous, and it exhibits no ſigns of fuſion, it may be conſidered as of the very beſt quality: but as it generally contains a variable proportion of iron, ſo its colour will exhibit more or leſs of a reddiſh-yellow tinge; and as this prevails, ſo the value of the clay will be materially impaired. A ſlight aſhery tinge

may be got rid of in the manufacture, by the addition of a little smalt; but the ware thus acquires a bluish tinge, which, though not very perceptible alone, is sufficiently obvious when compared with porcelain made of pure unsophisticated clay.

The common clays, or those that belong to the third subspecies, may be divided, with regard to their utility, into the three classes of unctuous, meagre, and calcareous.

The unctuous contains, in general, more alumine than the meagre, and the siliceous ingredient is in finer grains: when burnt, it adheres strongly to the tongue, but its texture is not visibly porous. When containing little or no oxyd of iron, it burns to a very good white colour, and is very infusible; pipes are made of it, and it forms the basis of the white Staffordshire ware. If it contains oxyd of iron, or pyrites, sufficient to colour it red when baked (as is usually the case), it becomes much more fusible, and can only be employed in manufacturing the coarser kinds of pottery.

Meagre clay is such as when dry does not take a polish from rubbing it with the nail: it feels gritty between the teeth, and the sand which it contains is in visible grains. When burnt without addition, it has a coarse granular texture, and is employed in the manufacture of bricks and tiles.

Calcareous clay effervesces with acids, is unctuous to the touch, and always contains iron enough to give it a red colour when baked. It is much more fusible than any of the preceding, and is only employed in brick-making: by judicious burning it may be made to assume a semi-vitreous texture, and bricks thus made are very durable.

Any of the unctuous or meagre clays, that are very infusible and contain but little iron, may be employed in making crucibles, and other similar chemical vessels, that are required to stand a powerful heat.

Clay, in *Agriculture*, a soft, earthy substance, of an unctuous and tenacious quality, and which is found in a native state in different situations. It has been remarked by Dr. Fordyce, to form a tenacious mass when mixed with water, which hardens upon drying, and does not diffuse so readily in water again as sand; and that if a mass of it be heated red hot, it becomes hard, and burns to a brick, resembling crystalline earth in its properties. It is also found that soap-earth agrees in its properties with clay, of which it is a species, only it is much more diffusible in water, separates from it with greater difficulty, is of a smoother texture, and has finer particles. It is a substance that by culture becomes more diffusible in water. The earth or soil consists chiefly of strata of substances, in which the clay and crystalline earth are sometimes found pure, but more commonly there is a mixture of the two; and it is seldomer that pure clay is found than pure sand. It has been remarked by Lord Dundonald, that this kind of matter forms not only a large portion of the surface-soil of most countries, but it is also found in the mineral strata to an immense depth; that argillaceous matter, or clay, is no where found pure, but is more or less adulterated with other earths, and with different materials, such as mineral, vegetable, and animal substances. And that the purest clay contains upwards of sixty per cent. of siliceous matter, or sand.

It is the earth most retentive of moisture, by which it becomes ductile and tenacious, and loses these properties by the action of fire, or by being burnt. According to Mr. Kirwan, it is of various colours, as white, grey, brownish red, brownish black, yellow, or bluish; it feels smooth, and somewhat unctuous; if moist, it adheres to the fingers, and if sufficiently so, it becomes tough and ductile. If dry, it adheres more or less to the tongue; if thrown into water, it gradually diffuses itself through it, and slowly separates from it. It does not usually effervesce with acids, unless a strong heat be applied, or that it contains a few calcareous particles, or magnesia. It consists of argill and fine sand usually of the siliceous kind, in various proportions, and more or less ferruginous matter. The argill, according to him, forms generally from 20 to 75 per cent. of the whole mass; the sand and calx of iron the remainder. These are perfectly separable by boiling in strong vitriolic acid.

It is remarked by Dr. Darwin, in his "Philosophy of Agriculture and Gardening," that the too great adhesion of the particles of argillaceous earth, or clay, renders it, in its pure state, unfit for vegetation; as the tender fibrils of roots can with difficulty penetrate it; whence it becomes much improved for the purposes of agriculture, when it is mixed with calcareous earth and with siliceous sand, as in marl. It is commonly believed, he also says, that lumps of clay become meliorated by being exposed to frost in its moist state, which, by expanding the water which it contains, by converting it into ice, is supposed to leave the particles of the clay further from each other. This, however, he says, seems in general to be a mistaken idea, since, if the act of freezing seems to occur, as noticed by Mr. Kirwan in his "Mineralogy," vol. i. p. 9, who observes, that clay, in its usual state of dryness, can absorb two and a half times its weight of water without suffering any to drop out, and retains it in the open air more pertinaciously than other earths, squeezing out its water, and thus parting with more of it than other earths. This curious circumstance, that water as it crystallizes detrudes the clay which is diffused in it, corresponds, he remarks, with other facts of congelation. Thus when wine, or vinegar, or common salt and water are thus exposed to frosty air, the alcohol, the acetous acid, the marine salt, and the calx of copper, are all of them detruded from the aqueous crystals, and retreat to the central part of the fluid, or to that last frozen, or into numerous cells surrounded with partitions of ice, as he has frequently observed; whence it appears, that wet clay is in general rendered more solid and tenacious by being frozen, as well as when it is dried, and its moisture exhaled by too warm a sun, and by both those circumstances becomes less adapted to the purposes of agriculture. In most clays a kind of effervescence occurs, after they are turned over and thrown on heaps, and thus acquire air into their interstices, which renders them much fitter for the purposes of vitrification, and thus forwards the processes of the brick-kiln and pottery. This greater facility to vitrify, is probably effected by the union of oxygen with the iron, which most clays contain; as oxydes of lead and manganese are used in the more perfect vitrifications. When the clay abounds with vitriolic acid, so as to be converted into alum, it becomes very unfriendly to vegetation.

It has been found in practice, that vast improvement in many of the lighter sorts of soil may be effected by the use or application of clay upon them. And Mr. Rodwell has experienced great improvement from it on the poorer sorts of sandy soils, which are very loose, and even on black sands. See Claying *of Land*.

It has also been remarked by Mr. Young, in speaking of marl, that when that substance "is not to be had, clay in many places is to be found at a moderate depth. This manure has," he says, "few of the properties by which marl is to be known, but yet it works wonderful improvements on many soils. In some light lands it has been preferred by many good farmers to indifferent sorts of marl; and this preference has been the result of attentive experience. But," continues he, "the great point concerning clay, is not so much the comparison with marl, as the use of it where no marl is to be had. On all light sandy soils it should be used with a confidence of success; for the precedents of its good effects are so numerous, that we cannot have a doubt of its excellence. About sixty or seventy loads an acre, at the same

expence as of marl, will work an improvement great enough to shew how much mistaken those men are who think nothing but the finest marls worthy of attention; and upon heavier soils, as wet loams, brick earths, upon clay, and loose hollow soils, that want a firmer texture, clay is an excellent manure; but there are vast tracts of such land that cover very fine veins of clay, and yet farmers know nothing of the use of it. It is much to be regretted," he thinks, "that their landlords do not give them a juster idea, by being at the expence of claying some small fields until the benefit of the improvement becomes conspicuous."

Clay *Balls*, in *Mineralogy*, are the name by which, in some places, the stony nodulous fossils called *Ludus Helmontii* are known. These are usually reckoned among the extraneous fossils, and are found of various sizes from four or five inches to almost as many feet in diameter; they are usually flattened irregularly, and appear externally, like masses of soft matter kneaded or moulded imperfectly together; their internal substance is cracked, apparently by the shrinking of their substance in drying or hardening, and the joints or septa are more or less coated or filled with spar, often of a waxen colour, whence this fossil is sometimes called *Septariæ*, or *Waxen-vein*. Clay-balls are found in many of the British clay strata, and are usually lodged therein with the utmost regularity, like pavement, often touching each other, as is the case with two remarkable layers of this fossil near the top of the clay on which London stands. In the cutting of the Grand-Junction canal from Paddington towards Uxbridge, and the Croydon canal from Deptford towards Croydon, these layers were cut through and exposed in a very complete manner for examination, for great distances together; they are sunk through in all the wells near London, where the clay stratum is complete, or where none of its upper part is abraded or washed away. Sometimes a small spring of water ouzes out of these layers of clay-balls, and the same is found to possess mineral qualities, and they are, we believe, the source of most or all of the mineral springs in the immediate vicinity of the metropolis. When exposed to the air, rain, &c. clay-balls soon split, and fall into an ochry powder, and at length mix with the soil; but the spar occupying the septa is sometimes very durable, and remains entire after the substance of the ball is mouldered away. An important use was a few years ago discovered for these curious nodules, in the manufacture of a cement for water-works and stuccoing of buildings, for which Messrs. Parker and Co. of Bankside, London, have a patent; they call it Roman cement, and the same is now largely used in the construction of the walls of docks, reservoirs, &c. and for imitating stone-work in buildings; the new door-cases to the Treasury-Chambers, in Whitehall, are a specimen of the valuable qualities of this cement, the same having been applied, in very thick layers at once, during an intense frost a few winters ago, and yet it set immediately, and stands the weather as perfectly as the best stone. The front of the House of Lords, and many other buildings in Westminster, are now covering with this cement, under the direction of Mr. James Wyatt, who has applied it with effect on the new palace at Kew, and in some additions and repairs at Windsor Castle. It is not certain that all the clay-balls, lodged in the different clay strata, are exactly similar in their composition, or adapted to the manufacture of cement; where, however, they can be had in plenty, it may be worth the while of the owners of the soil to procure their analysis and trial. See Ludus Helmontii.

Clay-*Castle*, in *Geography*, is situate about a mile S.W. from Youghal, in the county of Cork, Ireland, where the pieces of the bank that break off and are washed down by the sea, are by degrees petrified into a hard firm grit. This is composed of a mixture of fine sand, and a yellow clay tempered by the sea water which beats against the hill. Wood and several other things daubed over with this clay are petrified on the spot. Smith says, there is a similar petrification at Harwich in England. Smith's Cork.

Clay-*Farms*, in *Agriculture*, such as have the lands either wholly or in a great part of a clayey quality. There are many extensive tracts in different parts of the kingdom where this sort of land prevails, and which have been often cultivated to much disadvantage from the want of a due mode of cropping, and their not having of course a sufficient proportion of green winter food for the support of the requisite number of live stock, and the raising of the necessary quantity of manure. It has been suggested that these inconveniences may be fully obviated by having recourse to the cabbage husbandry. See Cabbage and Farm.

Clay *Hill*, or Copt Heap, in *Geography*, a remarkable eminence on the south west branch of the grand ridge of England, about two miles W. of Warminster, and near the edge of the Chalk strata. The situation of the barrow or tumulus on the top of this hill was determined in the government trigonometrical survey in 1794, by an observation from Beacon-Hill station, distant 117,216 feet, and bearing 85° 54″ 8″ S.E. from the parallel to the meridian of Dunnose; and another from Wingreen station distant 84,554 feet; whence is deduced its latitude 51° 12′ 13″, and its longitude from Greenwich 2° 13′ 25″.8 W. or 8ᵐ 53ˢ.7 in time.

Clay-*Mill*, a machine used by the brick-makers near London for tempering their clay. In *Plate* XII. *Mechanics*, are represented two of these machines. In *fig.* 10, which is the most common, A B is an upright shaft turning on a pivot at the lower end, which works in a brass socket let into a piece of wood lying on the ground; the upper end has a similar pivot, the brass is fixed in the intersection of two beams, C D, of the frame; these beams are supported by four uprights at their ends, which are firmly fixed in the ground; the whole is braced together so as to form a very steady frame for the shaft A B to turn round in. E, F, G, H, are four arms mortised in the shaft somewhat below the middle, supported by braces from the upper part of the shaft, and connected together by four braces in the form of a square; the two arms, E, F, are longer than the other two, and have hooks, by which the horses draw, fastened to them. They have also each two irons, *ab*, *ab*, attached to them, whose lower ends work at the sides of a circular trough or ditch, KK, which is concentric with the shaft A B, and walled with bricks. The ends of the levers, G, H, carry harrows, L, M, (*fig.* 11.) working in the same trough; these harrows are sometimes fixed to the arms, as at G, by three struts, and sometimes they are connected with the levers by four chains, and loaded with heavy weights, as at H, and better explained in the following figure.

When the machine is in use, a quantity of clay is thrown into the circular trough, K K, which is about one-fourth filled with water by a pump, the trough from which is laid under the horse-walk. The horses are then put to the ends of the levers, E, F, and set in motion; as they turn the machine round, the harrows, L, M, drag the clay round, in the trough, and by agitating it in the water, soon dissolve part of the clay, forming it into the consistence of thick mud; as the horses continue to work and more water is added, the whole mass is thoroughly incorporated; a sluice, N, is then opened which allows the clay to run out into shallow pits, which are dug in the ground at some distance round the mill, and a little below its level; in these pits the clay is suffered to remain until the greater part of the water is evaporated; it is then dug out and carried to the brick-maker. The pump

for ſupplying the mill, is in general worked by a man, but in the machine before us, it is worked by the mill; at the upper end of the ſhaft, AB, *fig.* 10. a wheel, P, is fixed, which has wooden projections nailed to it; theſe take the end of a lever, Q, moving on an iron bar, *d*, as a center; the weight of the lever is ſupported by a friction-wheel running on an horizontal bar R, fixed to the frame-work above; the lever, Q, has a rod, S, jointed to it near its end, which is ſupported by a frame, T, faſtened to one of the upright poſts, the end of this rod is jointed to one arm of a bent lever, the other arm of which has the pump-rod of the pump, O, hooked to it. As the horſes turn the wheel its teeth move the end of the lever Q with it and raiſe the pump-rod; when the tooth quits the end of the lever the weight of the pump-rod pulls back the lever to its original poſition, ready for the next ſtroke; by this contrivance a conſtant ſupply of water is eaſily procured, and, by preventing the deſcent of the pump-rod, the pump-work is ſtopped when there is water enough. The iron bars, *a b*, *a b*, are intended to remove the clay which may get to the ſides of the trough K K, and by that means eſcape the harrows.

The machine repreſented by *fig.* 11, though not ſo common, is much more ſimple in its conſtruction. A is a ſtout poſt firmly fixed in the ground; it is hooped at top, and has a braſs ſocket in the centre to receive the point of an iron pin, *a*, which goes through the interſection of two levers, E F, G H; this pin has a caſt-iron plate, *b*, faſtened to it, that is bolted to the lever, ſo as to connect them together. I, I, I, I, are four braces to ſtrengthen the croſs. O, O, O, O, are four other braces which carry a circular ring, R, and the whole is ſtrengthened by four long ſcrew bolts *d, d, d, d*; this ring fits the poſt looſely, and when the horſe turns the machine it moves as ſteadily as the former machine; the harrows and the circular trough are the ſame. The two preceding machines are uſed, in thoſe places where the clay uſed by the brick-makers is not very clean, but has many ſtones and other extraneous matter among it, as they ſink to the bottom of the circular trough, and remain there when the clay is drawn off. Where the clay is naturally ſufficiently pure, and requires only to be tempered, a different machine is uſed; it conſiſts of a cylindric tub about three feet diameter and four feet high, in the centre of which is a vertical ſpindle, the lower end working in a braſs ſocket at the bottom of the tub, the upper end turns in a collar ſupported by two iron bars nailed to the ſides of the tub; at the top of the ſpindle, above this collar, a long lever is fixed for the horſe to turn the ſpindle by; the upright ſpindle has ſix or eight arms fixed perpendicularly to it in different planes, working within the tub; theſe arms have ſpikes projecting from their upper and under ſides, the tub has a ſmall trap door in the ſide, near the bottom, which can be kept cloſed by a haſp; the clay is thrown in at the top of the tub, and the horſe made to turn the ſpindle, the arms and the ſpikes fixed to it, cut the clay in every direction and mix it thoroughly, water being added in the proper quantity. When it is ſufficiently ground the door at the bottom of the tub is opened, and, as the horſe turns, the clay is thrown out, and carried to the brick-maker.

Clay-*Stone*. See Clay *indurated*.

Clay *Strata*, in *Mineralogy*. The recurrence of clayey ſtrata, in the ſinking of deep wells, and ſhafts for mines, in England, is more common than thoſe of any other matter; and ſince the diſcoveries, and meritorious labour of Mr. William Smith, on the ſtratification of theſe iſlands, have been known among the circle of his friends, opportunities have offered, of aſcertaining the peculiarities of the organic remains moſt commonly lodged in theſe ſtrata. In the ſouth-eaſtern part of England, or uppermoſt parts of the ſeries of Britiſh ſtrata, theſe are, cornua ammonii, belemnites, corallines, or coralloids, entrochi, gryphites, bituminous wood, &c.; at the ſame time that ludus helmontii, iron-ore, or ochre, pyrites, ſelenite, or gypſum, mica, &c. are not unfrequently found lodged in theſe clay ſtrata.

The uppermoſt, or firſt clay ſtratum (or rather aſſemblage of clay ſtrata) in the Britiſh ſeries, is that on which the metropolis of the Britiſh empire and its environs ſtand; its upper part is red, and very tenacious when wet, forming perhaps one of the worſt ſtrata for cultivation, in England; which, but for the great population thereon, and conſequent opportunities of obtaining manure, for a ſeries of ages back, would probably, to the preſent day, have been in a ſimilar ſtate to the waſtes or commons, with which the vicinity of London has been ſo often reproached. Near the top of this ſtratum, there are two remarkable layers of clay-balls, or ludus helmontii, as obſerved under the article Clay-*Ball*, and lower down, pyrites, and other foſſils; a layer or ſtratum of ſand, containing black particles, occurs near the bottom of the London clay ſtrata, which, in the ſinking of wells, is ſometimes found nearly dry, and at others produces a ſpring of unpalatable water. Beneath the London clay ſtrata, a thick ſand ſtratum is found, reſting upon the chalk ſtrata, and, by means of the numerous and large cracks and fiſſures in the *chalk*, the ſand is ſupplied with a moſt powerfully pent or confined ſpring, which often riſes near 250 feet, on the ſinking of a well, through the clay ſtrata above mentioned, and runs over the ſurface, as in Mr. Vulliaumy's well, near Kenſington Gravel-pits, deſcribed in the "Philoſophical Tranſactions" for 1797, and many others in and near London, which have been ſunk within a few years paſt. Near the bottom of the London clay ſtrata, there are layers, or ſtrata, of ſmooth, flat, and round chert pebbles, of uniform ſizes, which do not appear to be worn or rounded fragments of a chert rock, but nodules, many of them conſiſting of concentric layers, originally formed, of the particular ſizes in which we now find them.

The next clayey ſtratum in the Britiſh ſeries, is found beneath the chalk ſtrata; from its white colour, it is denominated chalk-marl in many places; when overflowed, and kept wet, by ſprings from the edge of the chalk ſtrata, as at the foot of the chalk hills N. of Dunſtable, this chalk-marl is very tenacious and barren; but where its out-crop is dry, as on the ſouth ſide of the North Downs, near Ryegate, Godſtone, &c. or the north ſide of the South Downs, as at Clayton, Plumpton, &c. its ſurface forms very good land, particularly for wheat; while the inner parts of it are, in ſuch ſituations, diſpoſed to harden into a ſubſtance almoſt like ſtone, in thin laminæ. Cornua-ammonii, ſhark's teeth, and a curious variety of extraneous foſſils, are found in this chalk marl, of which we hope that the publication of Mr. Smith's intended work, will enable us to give a more detailed account, under the head of each foſſil, as we arrive at the ſame in the progreſs of our work.

The next conſiderable aſſemblage of clay ſtrata which we meet with in the Britiſh ſeries, has a remarkable ſtratum of red potter's-clay on its ſurface, on which there is a variety of tile and pottery kilns in Suſſex, beneath which a whitiſh tenacious clay is found, and therein a thin ſtratum of lime-ſtone, called Suſſex marble, in many places where it is uſed, particularly in the ſlender grouped pillars of Gothic buildings, like Weſtminſter Abbey; this thin and curious ſtratum of lime-ſtone, conſiſts almoſt entirely of a congeries of turbinated, or perriwinkle-like ſhells, of very uniform ſizes; in ſome ſpecimens theſe are all ſmaller than peaſe, and in others they are of the ordinary ſize of perriwinkles; whether theſe are the produce of different beds in the ſame ſtratum, or whether a thickneſs of clay ſeparates them, we have not yet been able

to ascertain. This subject we must, for the reason above stated, resume on future occasions.

The most usual vegetable productions found upon clay strata, are of the following genera; *viz.* in wet situations, carex, juncus, schœnus, aira, orchis, carduus, poterium, salix, &c. while, in dry situations, the following prevail, *viz.* primula, arum, rhinanthus, orchis, poa, rosa, rubus, prunus, acer, quercus, &c.

Coal

COAL, in *Mineralogy*. The word coal has been derived by fome writers from the Hebrew, and by others from the Greek or Latin, but whatever may be its origin, it is deferving of remark that the fame found for the fame object is ufed in the Anglo-Saxon, the Teutonic, the Dutch, the Danifh, and the Iflandic languages. Coals are found in feveral parts of the continent of Europe, but the principal mines are in this country. They have been difcovered and wrought in Newfoundland, Cape Breton, Canada, and in fome of the provinces of New England. China abounds in them, and they are well known in Tartary, and in the ifland of Madagafcar.

Hiftory of Coal as an Article of Commerce.

Coals are firft mentioned as fuel for artificers by Theophraftus, who defcribes them as earthy fubftances that burn like wood-coals, and are ufed by the fmiths. The ancient Britons had a primitive name for this foffil, and Pennant fays, "that a flint axe, the inftrument of the aborigines of our ifland, was difcovered in a certain vein of coal in Monmouthfhire, and in fuch a fituation as to render it very acceffible to the inexperienced natives, who in early times were incapable of purfuing the feams to any great depths."

Although coals are fo abundant in many of the above named places, yet as there are no beds found in the whole extent of Italy, the great line of this fuel feems to fweep round the globe, from the north-eaft to the fouth-weft, vifiting Brabant and France, and avoiding Italy. The ftrongeft argument adduced by thofe who contend that the Romans, while in poffeffion of this ifland, were ignorant of the ufe of coal, is, that there is no name for it in the Latin language, the word *carbo* being always ufed for charcoal. Cæfar takes no notice of coal in his defcription of this ifland; yet there is good evidence to believe that the Romans brought it into ufe. In the Weft Riding of Yorkfhire are many beds of cinders, heaped up in the fields, in one of which a number of Roman coins were found fome years ago.

From Horfely it appears, that there was a colliery at Benwell, about four miles weft of Newcaftle-upon-Tyne, fuppofed to have been actually worked by the Romans, and it is evident from Whitaker, that coals were ufed as fuel in this country by the Saxons. No mention is made of this foffil during the Danifh ufurpation, nor for many years after the Norman conqueft.

The first charter for the licence of digging coals, was granted by king Henry III., in the year 1239; it was there denominated sea-coal; and, in 1281, Newcastle was famous for its great trade in this article, but in 1306, the use of sea-coal was prohibited in London, from its supposed tendency to corrupt the air. Shortly after this, it was the common fuel at the king's palace in London, and, in 1325, a trade was opened between France and England, in which corn was imported, and coals exported. In 1379, a duty of sixpence per ton was imposed upon ships coming from Newcastle with coals. At this period, the inhabitants of the county of Durham had obtained no privilege to load or unload coals on the south side of the Tyne; but, in 1384, Richard II., on account of his devotion to Cuthbert, the tutelary saint of Durham, granted them licence to export the produce of their mines, without paying any duties to the corporation of Newcastle. In the year 1421, it was enacted, that the keels or lighters carrying coals to the ships should measure exactly twenty chaldrons, to prevent frauds in the duties payable to the king.

Æneas Sylvius, afterwards pope Pius II., visited this island, about the middle of the 15th century, and he remarked, that the poor of Scotland received for alms pieces of stone, which they burnt in place of wood, of which at that time the country was destitute. About the beginning of the 16th century, the best coals were sold in London at the rate of 4*s.* 1*d.* per chaldron, and at Newcastle for about 2*s.* 6*d.*; and in 1563, an act was passed in Scotland to prevent the exportation of coals, which had occasioned a great dearth of fuel in that country. Queen Elizabeth, in the year 1582, obtained a lease of a great part of the mines of Durham, for ninety three years, at the annual rent of 90*l.*, which occasioned an advance in the price of coals; it was afterwards assigned to Thomas Sutton, the founder of the Charter-House in London, who assigned it to the corporation of Newcastle, for the sum of 12,000*l.*; and the price of coals was immediately advanced to seven shillings and eight shillings per chaldron. Notwithstanding the several advances upon this article, when queen Elizabeth demanded the arrears of two-pence per chaldron, which had been granted to Henry V., but the payment of which had been neglected by the corporation, they petitioned for a remission of the debt on account of their inability; this was granted, and also a charter to incorporate a new company, called hostmen or coal-engrossers, for selling all coals to the shipping; in consequence of which the corporation imposed one shilling per chaldron additional upon this article. At this period the lord mayor of London complained to the lord-treasurer, Burleigh, that the free-hosts in Newcastle, to whom the grand-lease had been assigned, for the use of the town, had transferred their right to a few persons, who engrossed all the other collieries, and he requested that the collieries might be free, and that the price of coals should not exceed seven shillings per chaldron.

It appears, by an order of the hostman's company, dated A.D. 1600, that tram-waggons and waggon-ways had not then been invented, but that the coals were at that time brought down from the pits in wains, holding eight bolls each (all of them measured and marked), to the staiths by the side of the river. About this period, an engine for drawing the water out of the coal mines was invented in Scotland, by a predecessor of the first earl of Balcarras, who obtained from James VI. a patent for 21 years. This improvement was not, till some time after, adopted in the neighbourhood of Newcastle.

In a petition of grievances, presented by the house of commons to king James, in 1610, a complaint occurs of a late imposition of one shilling per chaldron on sea-coals, rising in Blyth and Sunderland, not by virtue of any contract or grant, as on the coals of Newcastle, but under the mere pretext, assumed by the contractors, of his majesty's royal prerogative. This petition displayed so strongly the rapacity of that body of men, and the distress occasioned by it to the inhabitants of London, that the prayer of the petition was immediately complied with. It was during the same reign, that an information was exhibited in the star-chamber, by the attorney-general, against the mayor and burgesses of Newcastle, by the name of hostmen, for that they, having the preemption of coals for the inheritors in Northumberland, and the county of Durham, by their charter of the 42d of Elizabeth, forced ships to take bad coals, amongst which was a quantity of slate; in consequence of this they were all fined, some of them in penalties of one hundred pounds each, and committed to the Fleet prison; and the decree was ordered to be read in the open market in Newcastle, two several market days.

In 1615, there were employed in the coal trade of Newcastle 400 sail of ships, one-half of which supplied London, the remainder the other part of the kingdom; the French too are represented as trading to Newcastle at this time for coal, in fleets of 50 sail at once, serving the ports of Picardy, Normandy, Bretagne, and as far as Rochelle and Bourdeaux, while the ships of Bremen, Embden, Holland, and Zealand, were supplying the inhabitants of Flanders.

In 1622, an order was issued by the hostmen, against the secret and disorderly loading of coals, but not until they had received several precepts from the king and privy-council, concerning this abuse. They were summoned to answer again, by process from the exchequer chamber, against the governor, stewards, and some others of the company, for the above default; and as we are not informed of the result of this proceeding, we may conclude it did not terminate in their favour. Soon after this, David Ramsay, a great projector, obtained an exclusive charter to raise water from low mines and coal pits, by a method entirely original. In the year 1630, the king let to farm an impost on coals of 5*s.* per chaldron, for those transported out of England, Wales, and Berwick-upon-Tweed, to any part beyond the seas, except Guernsey, Jersey, and the Isle of Man; of 1*s.* 8*d.* over and above the 5*s.* on those to be exported, as above, by any Englishman; and also of 3*s.* 4*d.* for every chaldron to be exported except for Ireland and Scotland. In 1631, an information was again made in the star-chamber, by Heath, attorney-general, against the hostmen of Newcastle, for mixing 40,000 chaldron of coals with slates, &c.; from whence it seems, that the former fines and imprisonment had no effect, but that they had still proceeded to cheat the metropolis and the country at large, even after those severe measures of government. A. D. 1634, the king, solely by his own authority, imposed a duty of four shillings per chaldron on all sea-coal, stone-coal, or pit-coal, exported from England to foreign parts.

In 1637, one shilling per chaldron appears to have been paid, on the foreign vent of coals, to the mayor of Newcastle and corporation. Government being applied to for redress, letters were sent to the bishop of Durham, requiring him to write to the said mayor, and order an immediate restoration of the above exaction; the bishop's letter is dated 10th of January, 1638. In 1643, when the Scots besieged Newcastle, all the coal-mines were, it is said, ordered to be set on fire, which was prevented by general Leslie, who took the vessels by surprize. In 1648, coals were so excessively dear in London, that many of the poor are said to have died for want of fuel. In November 1653, articles were again ex-

hibited against the town of Newcaſtle, concerning the coal-trade; and the cauſe, as uſual, was given againſt them. About this time the port of Sunderland appears to be riſing into importance. In 1667, coals are ſaid to have been ſold in London for above 20*s.* a chaldron; about 320 keels were at that time employed upon the river Tyne, in the coal trade, each of which carried annually 800 chaldrons on board the ſhips. To adjuſt the difference of meaſures it muſt be noted, that 16 chaldrons of Newcaſtle, are equal to 31 of London pool meaſure, according to Mr. Eddington. In 1656, the cuſtoms upon all coals exported, were let to Mr. Martin Nowel at 22,000 pounds per annum, of which ſum 19,783*l.* 14*s.* 8*d.* were for the coals of England, and 2,216*l.* 5*s.* 4*d.* for thoſe of Scotland. Commiſſioners were now appointed by the lord protector, under the great ſeal of England, for the meaſuring of keels, which was performed in a new and better manner than had been before known. In December 1667, the parliament made an order, that the price of coals, till the 25th of March following, ſhould not exceed 30*s.* per chaldron; and by an act made that year, after the great fire in London, a duty of one ſhilling per chaldron was granted to the lord mayor of that city, to enable him to rebuild the churches, and other public edifices. This, however, being inſufficient, it was made three ſhillings, to continue twenty years. In 1677, Charles II. granted to the duke of Richmond one ſhilling per chaldron on coals brought to London, which was continued in the family till the year 1800, when it was purchaſed by government, for the annual ſum of 1,900*l.* payable to the duke and his ſucceſſors. This duty at preſent produces to government 2,500*l.* annually. At the end of the ſeventeenth century, 1400 ſhips are ſaid to have been employed in exporting yearly from Newcaſtle, two hundred thouſand chaldrons of coal, Newcaſtle meaſure, which was about two thirds of the whole trade. The over-ſea trade in this article, at the ſame time, employed nine hundred thouſand tons of ſhipping. In 1710, a duty was laid upon coals for building 50 churches; a curious and particular account of the monies collected by duties on coal, for the building of St. Paul's church, in London, from October 1, 1668, to May 5, 1716, is preſerved in the Antiquarian Repoſitory, vol. ii. page 40. In the year 1741, a drawback was granted on the duty on coals, uſed in fire-engines for working the tin and copper mines in Cornwall. Mention occurs in 1758, of a machine invented by Michael Meinzies, eſq. by which coals were drawn up, not by the ſtrength of horſes or of men, but by the deſcent of a bucket full of water, of a weight ſuperior to that of the coals drawn up, lifting a corve of ſix hundred pounds weight, out of a pit about fifty fathoms deep, in two minutes. A machine, nearly ſimilar, was afterwards erected at Worſley, by James Brindley, on the duke of Bridgewater's canal, and is mentioned in our article CANAL. See alſo *bucket* ENGINE. In the year 1764, there were exported from the river Tyne, for London, and coaſtwiſe, twenty thouſand chaldrons of coals, and forty thouſand chaldrons of London meaſure for foreign parts, more than had been exported in any one year. From the years 1770 to 1776, were ſhipped to London, and other parts of Great Britain, 351,000 chaldrons of coals, of which 260,000 were ſent to London: to the Britiſh colonies and plantations, 2,000 chaldrons; and exported to foreign parts, 3,700; in all, averaging 380,000 chaldrons, Newcaſtle meaſure, per annum. The weight of theſe, at 53 cwt. per chaldron, is one million, ſeven thouſand tons; the duty paid to the crown at the ports of diſcharge, on 351,000 chaldrons, at 5*s.* per chaldron, is 167,000 pounds.

In 1776, from a note communicated by the ſurveyor of the cuſtoms of Newcaſtle, we find, that 14,000 chaldrons were exported in that year from Blyth; 18,000 chaldrons from Hartley Haven; 350,803 chaldrons from Newcaſtle, coaſtwiſe.

The trade, thus rapidly encreaſing, acquired its preſent importance. The following account of coals exported from the river Tyne, in the years 1802, 1803, 1804, and 1805, will give an idea of the amazing extent to which it is now carried.

	Coaſtwiſe.	Over-ſea.	Plantations.
In the year 1802	494,483	41,157	2844
1803	505,137	42,8[illegible]8	1516
1804	579,929	48,737	3852
1805	552,827	47,213	2360

We do not here include the quantity exported from the harbours adjoining near to Newcaſtle, *viz.* Sunderland, which exports, annually, about three hundred thouſand chaldrons; and Blyth and Hartley, which alſo export conſiderable quantities; neither do we notice the proportion conſumed in the town and neighbourhood of Newcaſtle.

It is calculated, that the ſum expended in materials for boring and ſinking for coal, ſuch as wood, iron, ropes, &c. independently of the money paid for the excluſive privilege of working, amounts, in ſome collieries, to upwards of 30,000 pounds per annum. By a calculation lately made, it is ſuppoſed that 64,724 people are employed by the coal trade on the rivers Tyne and Wear. See theſe under our article CANAL. The following is a calculation of the capital employed in the ſame trade.

In the collieries -	1,030,000
In ſhipping - -	1,400,000
Capital employed by the London coal-merchants -	700,000
Total	3,130,000

From this detail, the coal-trade muſt appear of the utmoſt importance, not only in a local, but in a national point of view, as a nurſery of excellent ſeamen for the Britiſh navy; and as the means of employment for many thouſands of induſtrious working people. Beſides the important advantages already enumerated, others deſerve to be noticed. Coal is in many reſpects, and in a very high degree, uſeful to the landed intereſt, not only by greatly enhancing the real value of thoſe lands in which it is found, and thoſe through which it muſt paſs, from the works to the place where it is ſhipped, but from the general improvements which it has occaſioned, in conſequence of the wealth it has brought into the country.

An act of parliament paſſed in 1803, as hereinafter mentioned, for preventing the mixing of coals of different ſorts together, by the dealers, before delivery in London and its environs; and for that purpoſe, it required the name of the coals contained in each ſhip's cargo to be certified to the buyers. It were much to be wiſhed, that ſome better criteria could have been adopted for aſcertaining the different ſorts of coals (the worſt of which often are, or rather ſhould be, ſelling in London at two thirds of the price of the beſt ſorts, or leſs,) than merely the names of the ſeveral pits' mouths out of which they were drawn; when it is well known, that all the deeper pits are ſunk through ſeveral veins of different qualities, and ſometimes have one of theſe veins in work, and ſometimes another, or perhaps ſeveral of them at the ſame time; whence the facility ariſes, of ſending better or worſe coals to market under the ſame name, according as the relative prices of good and bad coals may induce: could not the names of the different veins which have diſtinct qualities, have been certified, along with the coals dug therefrom, inſtead of the arbi-

trary, and perhaps worſe than uſeleſs name of the pit, containing ſeveral veins exactly the ſame with, and actually opening into the works of the neighbouring pits? The following is an alphabetical liſt of the names of the different cargoes of coals publiſhed in the newſpapers, as ſold at the coal-exchange, London, during a conſiderable period, with the name of the river, canal, or port from which they were put on ſhip-board, after being conveyed thither by rail-ways, &c. (ſee our article CANAL) and a ſeries of numbers, expreſſing the number of times that each name appeared among the coal-exchange ſales of the day, during the period alluded to.

Adair's Main	*Tyne*	126
Allan's Main	*Wear*	1
Baker's Main	*Tyne*	16
Bedford Main	*Wear*	45
Bedworth	*Grand Junction.*	
Benton	*Tyne*	301
Benwell	*Tyne*	4
Biddick Main	*Wear*	17
Bigg's Main	*Tyne*	419
Bitley Moor	*Wear*	3
Blyth	*Blyth*	199
Boundry Main	*Wear*	14
Bourn Moor Main	*Wear*	343
Brandling Main	*Tyne*	141
Byker	*Tyne*	73
Cowper Main	*Blyth*	122
St. David's	-	17
Eden Main	*Wear*	138
Eighton Main	*Tyne*	51
Elmore Main	*Tyne*	3
Flatworth	*Tyne*	6
Flocton	-	2
Gate's Head Park	*Tyne*	2
Greenwich	-	42
Harecaſtle	*Grand Junction.*	
Harraton	*Wear*	3
Hartley	*Seaton Burn*	232
Heaton Main	*Tyne*	359
Hebburn Main	*Tyne*	377
Hollywell Main	*Tyne*	178
Howard's Main	-	2
Hutton Seam	*Wear*	2
Kenton, Eaſt and Weſt	*Tyne*	103
Lambton Main	*Wear*	6
Lawſon's Main	-	5
Marley Hill	*Tyne*	3
Montague Main	*Tyne*	266
Murton Main	-	12
Newbottle	*Wear*	90
Newton	-	4
Percy Main	*Tyne*	1
Pontop, Simpſon's	*Tyne*	48
——— Windſor's	*Tyne*	154
Primroſe Main	*Wear*	32
Rectory Main	*Tyne* or *Wear*	87
Ruſſel's Main	*Tyne* or *Wear*	153
Scotch Coal	-	3
Sheriff Hill	*Tyne*	105
South Moor	*Tyne*	122
Stanley	-	8
Tanfield Moor	*Tyne*	115
———— Pitt's	*Tyne*	154
Team	*Tyne*	94
Tyne Main	*Tyne*	25
Uſworth	*Tyne*	4
Wallbottle Moor	*Tyne*	101
Walker	*Tyne*	292
Wall's End	*Tyne*	468
Warwick Main	*Wear*	55
Wedneſbury	*Grand Junction.*	
Wentworth	*Wear*	28
Weſtfield	-	7
Wharton	*Wear*	1
Whitfield	*Tyne*	15
Willington	*Tyne*	337
Wooler	-	12
Wylam Moor	*Tyne*	152

The number of the different ſorts of coals as above, which were in one day on ſale in the market, on four particular occaſions, within the above period, amounted to 24; on three market days, there were 23 different ſorts ſold; on three days, 22 ſorts; on two days, 21 ſorts; on eight days, 20 ſorts; on ſeven days, 19 ſorts; on 10 days, 18 ſorts; on 18 days, 17 ſorts; and on 235 market days, cargoes of from 10 to 15 different ſorts of coals, were reported as ſold in the London market.

From the above table, the proportionate frequency of demand and facility of ſupply in London, for different ſorts of coals, appears to have ſtood as follows, *viz.* Wall's end, Bigg's main, Hebburn main, Heaton main, Bourn moor main, Willington, Benton, Walker, Montague main, Hartley, Blyth, Hollywell main, Pontop (Windſor's), Tanfield moor (Pitt's), Ruſſel's main, Wylam moor, &c. The order of the different ſorts of coals, as to price per chaldron, on ſhip-board in the pool, have, on ſeveral occaſions, ſtood as follows, beginning with the higheſt, *viz.* Wall's end, Percy main, Bigg's main, Heaton main, Hebburn main, Kenton, Walker, Willington, Benton, Montague main, Adair's main, Eighton main, Cowper main, Tanfield moor, Pontop, Brandling, Blyth, Bourn main, Team, Hartley Newbottle, Ruſſel's main, Bedford main, Hollywell main, Wallbottle, &c. Theſe prices are of courſe ſubject to vary conſiderably, according as the veſſels arrive in conſiderable numbers or not, with the ſorts which happen to be at that time in demand. We have been at conſiderable pains in collecting the above particulars, in order to throw all the light in our power upon a branch of commerce, of the firſt importance in a national point of view, but particularly ſo to the metropolis, whoſe proſperity and comforts ſo much depend upon it. In Eddington's "Eſſay on the Coal Trade, 1803," many highly uſeful particulars on this ſubject will be found.

By 30 C. II. ſt. 1. c. 8. and 6 and 7. W. c. 10. and 11 G. II. c. 15. a penalty of 10*l.* is enacted, for defacing marks on keels, boats, waggons, &c. uſed for the carriage of coals in the ports of Newcaſtle, Sunderland, &c.; and by 15 G. III. c. 27. extended to the other parts of this kingdom. By 31 G. III. c. 36. regulations are enacted to the ſame purpoſe; and any perſon convicted of removing, defacing, or deſtroying ſuch marks, is ſubject to the forfeiture of a ſum not leſs than 40*s*, and not exceeding 5*l.* By 12 Ann. ſt. 2. c. 17. every coal-buſhel ſhall be round, with an even bottom, be 19½ inches from outſide to outſide, and contain one Wincheſter buſhel; and all ſea-coal and culm, chargeable with any duties by the Wincheſter meaſure, ſhall be charged, ſold, meaſured, and paid by the chaldron, containing 36 ſuch buſhels heaped up. By 17 G. II. c. 35, three juſtices may ſet the retail price of coals, after landing in any place to which the 16 and 17 G. II. reſpecting the price of coals brought into the river Thames, doth not extend, as they ſhall judge reaſonable. Concerning the weights, meaſures, and prices of coals, eſpecially in and about London; and alſo concerning the duties upon them, there are various regulations enacted by about 40 different acts of parliament,

which we shall not recite. The stat. 43 G. III. c. 134, which is an "act for establishing a free market in the city of London, for the sale of coals, and for preventing frauds and impositions in the vent or delivery of all coals brought into the port of London, within certain places therein mentioned," situate within the distance of 25 miles from the Royal Exchange, in the city of London, empowers the corporation of London to purchase the coal-exchange in the said city, and regulates the mode of indemnity to those whose buildings may be requisite for the purposes of the said act. For preventing the sale of one sort of coals for another, the vender and dealer shall forfeit, for every such offence, 20*l.* per chaldron so sold; and such vender or dealer shall not be subject to any penalty inflicted by the 3 Geo. II. c. 26, on every person who shall knowingly sell one sort of coals for, and as a sort of coals which they really are not; provided always, that no ship-owner, master, or other person, having the care or command of any vessel within the said port of London, shall be subject to such penalty in respect of any number of chaldrons exceeding 25 chaldrons, for the same cargo of coals. This act directs, that no coal-meters or coal-heavers shall be unnecessarily detained on board a ship, and settles how the wages of coal-heavers shall be paid; it also requires, that ship-meters shall give certificates of the coals delivered in each lighter; and that no fractional part of five chaldrons shall be delivered into any room of a barge, under a penalty of forfeiture in the first case, of a sum not exceeding 10*l.*, and in the latter not exceeding 20*l.* This statute further enjoins and prescribes the mode of remeasuring coals by the vat; and also enacts, that in case the coals so remeasured shall not amount to the quantity mentioned in the certificate of such ship-meter as required by this act, the coal-meter, who measured them from the vessel into the craft, shall, for every bushel found deficient, if the deficiency be not equal to three bushels in five chaldrons, forfeit 5*s.* per bushel, and if such deficiency shall equal or exceed three bushels in five chaldrons, then such meter shall forfeit 5*l.* per bushel; and also the expences of placing the vat for the remeasurement. Carmen are required to carry a bushel measure in their carts, of the form, size, and dimensions directed by the 12 Ann. c. 17; and the carmen, not having such measure, shall, for every offence, forfeit not exceeding 10*l.* nor less than 40*s.*; and the vender or dealer in such coals, shall forfeit not exceeding 20*l.* nor less than 5*l.* Carmen are also to deliver a printed ticket in a prescribed form, previous to the delivery of any coals; and in default of such delivery, for every such offence forfeit not exceeding 10*l.* nor less than 40*s.* Meters are forbidden to give certificates without actually measuring the coals comprised in them, under forfeiture of a sum not exceeding 20*l* if it shall appear upon the remeasurement of such coals, or any part thereof, that any sack shall not contain three bushels; then the vender of, or dealer in such coals, shall for every sack of coals deficient, on the remeasurement, forfeit not exceeding 40*s* for every sack so found deficient. Every sack used for the delivery of coals within the limits determined by this act, shall measure in the inside, at least four feet two inches in length, by two feet one inch in breadth, under a forfeiture of a sum not exceeding 40*s.*; and no sack shall, after the passing of this act, be marked at the Guildhall of London, or at the exchequer at Westminster, that shall measure less than above. The penalty on carmen for driving away coals without measuring, when required, for every such offence, is a forfeiture of a sum not exceeding 10*l.*; and the vender or dealer shall incur the same forfeiture; and such coals shall be forfeited for the benefit of the poor.

From this account of coal, as an article of commerce, and the laws relating to it, we now proceed to its natural history. There are three genera or families of coal; *viz.* brown coal, black coal, and uninflammable coal.

I. Family.—*Brown Coal.*

Sp. 1. *Common brown Coal, Bovey Coal, Surturbrand,* or *bituminized Wood.* Its colour is light brownish black; it occurs in mass; its longitudinal fracture is fibrous lamellar, passing into slaty or woody, and is slightly glimmering; its cross fracture is more or less conchoidal, with a shining resinous lustre; it acquires a polish by friction, and is moderately hard. Sp. gr. 1.4, when pure, but when mixed with pyrites, it is often considerably heavier.

It burns with a weak flame, like half-charred wood, giving out an unpleasant bituminous odour; when ignited in an open fire, it leaves a small quantity of white ashes. According to Mr. Hatchett (Phil. Trans. for 1804), 100 parts yield by distillation

30.	Acidulous water.
10.5	Thick, brown, oily bitumen.
45.	Charcoal.
14.5	Hydrogen, carbunetted hydrogen, and carbonic acid.
100 0	

It is found in England at Bovey, near Exeter, and in smaller quantities in the island of Purbeck, some parts of Hampshire, Sussex, &c. lodged in pipe-clay. It is also found in the territory of Hesse and other parts of Germany, in Denmark, Iceland, Greenland, Italy. Faro islands, &c.

Sp. 2. *Moor Coal.* Its colour is dark blackish brown; it occurs in mass, forming thick beds, which are full of rifts and cracks. Internally, it exhibits a bright resinous lustre; its longitudinal fracture is imperfectly slaty, its cross fracture is even, approaching to flat conchoidal. It breaks into rhomboidal fragments. It is very tender, easily frangible, and of low specific gravity.

It is found in Bohemia, Transylvania, in Denmark, the Faro islands, &c.

II. Family.—*Black Coal.*

Sp. 1. *Slate Coal.* Its colour is pure black, or greyish-black, and is often iridescently tarnished. It occurs in mass, and commonly possesses a high resinous lustre. Its longitudinal fracture is slaty; the cross fracture is small grained, uneven, passing into flat conchoidal. It breaks into angular fragments. It is soft and easily frangible. Sp. gr. 1.25 to 1.4. It contains from 57 to 64 per cent. of charcoal, from 33 to 43 per cent. of bitumen, and from 3 to 6 per cent. of earth and oxyd of iron. The bitumen is partly in the state of asphaltum, and partly in that of maltha; in proportion to the prevalence of the former, is the caking quality of the coal.

Almost all the common coals, as pit coal, sea-coal, caking-coal, bituminous coal, run-coal, rock coal, &c. belong to this species.

Sp. 2. *Pitch Coal,* or *Jet* Its colour is velvet black. It occurs in mass, in plates, and sometimes in the shape of branches and trunks, with the true ligneous texture. It has a brilliant resinous lustre, and a conchoidal fracture. It is soft and brittle. Sp. gr. 1.3. It burns with a greenish flame and a strong bituminous odour. It occurs in Spain, the south of France, and in the Prussian amber mines, where it is called black-amber. In France, this substance is manufactured into buttons, beads, and other trinkets.

Sp. 3. *Cannel,* or *Candle-Coal, Splent Coal,* or *Parrot-Coal of Scotland.* Its colour is dark greyish black It occurs in mass, and has a glistening resinous lustre. Its frac-

ture is conchoidal. It is much less frangible than common coal. Sp. gr. 1.23. It is very inflammable, and crackles and flies while burning. It flames much and burns quickly, does not cake, and leaves from 3 to 4 per cent. of ashes. The splent-coal of Scotland is a coarse slaty variety of the above, containing pyrites, and leaving, after combustion, about 20 per cent of ashes.

Cannel coal occurs occasionally in the Newcastle pits, in Ayrshire in Scotland, and elsewhere, but the largest beds of it, and of the purest kind, are near Wigan in Lancashire. It is an excellent fuel; it will take a good polish, and may, with care, be turned in a lathe, into snuff-boxes and other trinkets, which are often passed off for true jet.

III. Family.—*Uninflammable Coal.*

Sp. 1. *Mineral Charcoal.* Its colour is greyish black. It occurs in plates and irregular pieces. It has a glimmering, silky lustre, and a fibrous fracture. It soils the fingers, is soft and friable. It is somewhat heavier than common charcoal, and burns to ashes without flaming. It generally occurs mixed with slate-coal.

Sp. 2. *Kilkenny Coal, Welsh Culm*, or *Stone-Coal.* Its colour is dark iron black, verging on steel-grey. It occurs in mass, has a bright metallic lustre. Its longitudinal fracture is slaty; its cross fracture is small and imperfectly conchoidal. Sp. gr. 1.5. to 1.8.

When laid on burning coals, it becomes red hot, emits a very light lambent flame, like charcoal, and is at length slowly consumed without caking, leaving behind a portion of red ashes.

The true Kilkenny coal is harder than Welsh culm, and of a brighter lustre; it often contains pyrites, and therefore gives a sulphureous odour when burning. This species of coal is found also in Hungary, Italy, and France.

These are the most considerable varieties of coal commonly known; but we must not imagine that each of them is to be met with in a pure state, in those places where they are found; on the contrary, the different qualities and proportions of their ingredients make a vast number of other varieties, fit for different purposes, according to the quality and quantity of those they contain. The various kinds of coals are often found mixed with each other under ground, and some of the finer sorts run, like veins, between those of a coarser. Mr. Magellan observed in the fine coals employed in a curious manufactory at Birmingham, that they produced a much clearer flame than he had ever seen produced from common coal, but, on inquiry, he found that these were picked out from the common coals of the country through which they ran in veins, and were easily distinguished by the manufacturers, though they did not afford sufficient indications of a specific difference. The purpose to which they were applied, was the moulding of rods of transparent and coloured glass, into shapes proper for common buttons, which the workmen performed with astonishing expedition.

On subjecting pit-coal of any kind to distillation in close vessels, it first yields watery liquor, then an ætherial or volatile oil, afterwards volatile alkali, and, lastly, a thick and greasy oil. But it is remarkable, that by rectifying this last oil, a transparent, thin, and light oil, of a straw colour, is produced, which, being exposed to the air, becomes black, like animal oils. From this and other observations, the general opinion is, that all coals, bitumens, and other oily substances found in the mineral kingdom, derive their origin from vegetables buried in the earth, during the successive processes of stratification; since it is well known, that only organized bodies have the power of producing oily and fat substances.

Before a coal-pit is sunk, it is necessary to explore the ground by boring, but if there are already pits in the neighbourhood, sections are obtained from them, which prevent the necessity of doing so.

Boring is accomplished in the following manner: The rods are made of iron, from three to four feet long, and one inch and a half square, with a solid or male screw at one end, and a hollow one at the other, by which they are fastened together, and as the hole formed by them increases in depth, other rods are added. The chisel is about eight inches long, and two and a half broad at the extremity, which is screwed on to the end of the lower rod, and a lever or handle is put through an eye at the top of the upper rod.

The mode of operation is, to lift up the rods a little, and then let them fall, turning them at the same time gently round; by a continuance of this motion, a hole is fretted, and worn by degrees through the hardest strata or rocks. The borers can fix on handles for two, three, or four persons to work as they find it necessary. After they get down to a certain depth, the rods are wrought by a bracke; a box of wood is first inserted into the ground, to keep the rods in a vertical or straight direction, and a triangle is erected over the spot where the boring is to be made (which is about three inches in diameter), for the sake of drawing up the rods; they have one key, or temporary handle, for unscrewing, and another for securing the rods from falling back again; they use a close wimble to bring up sludge and soft matter. When the chisel is blunted, or has cut down four or six inches, the rods are lifted up, either all together, if there be convenience, or by pieces, when a key is used to keep the rods from dropping down the hole; the chisel is screwed off, and the wimple or scoop screwed on. This being put down, brings up afterwards the dust or pulverized matter of the stratum through which the chisel has cut, and shews as well what kind of matter they are boring in, as the exact depth thereof.

A considerable improvement in this essential operation was made a few years ago, by Mr. James Ryan, a gentleman of Ireland, for which he took out patents in 1805; a copy of that for England may be seen in the 2d series of the "Repertory," vol. vi. p 324; this consists in using a cylindrical cutter, something like the surgeon's trepan-instrument, by which a core, or solid and unbroken piece of each stratum, is cut, and by other tools brought vertically to the surface, in the exact position as to the cardinal points, in which it stood in the strata, and thus the quantity and direction of the dip, as well as the exact nature of the strata or measures, are correctly ascertained, the former being most essential circumstances towards determining the proper place to sink an engine shaft, for draining the bed of coals intended to be worked. The borers and apparatus of Mr. Ryan are calculated to form a hole of any size, from eight inches to near as many feet in diameter; some of two feet diameter have, we are told, been actually sunk thereby, to a considerable depth, and answer the purposes of pump and air-shafts, and that one, nearly eight feet in diameter, is now sinking thereby in Ireland! In April, 1807, Mr. Ryan presented a complete set of his apparatus to the Board of Agriculture in London, and bored a hole of some depth therewith near Kensington, under the inspection of some of its members; the cores or borings therefrom, being exhibited to the Board, and lodged with the apparatus in their repository, they voted a pecuniary reward to Mr. Ryan. From the apparent im-

portance of this discovery to mining, but to coal-finding in particular, we were induced to wish, to give an accurate description and drawings in this place of Mr. Ryan's apparatus and process, but found the time too short, after the Board of Agriculture became possessed of the same, to do it here; under the article MINING, we shall endeavour to give them in the further state of perfection, in which practice will doubtless then present the same.

Boring is of the utmost use and importance in collieries, for by boring previously to the sinking of a pit, the owners procure most essential data on which to proceed, being informed before hand of the nature of the earth, minerals, and waters through which they have to pass, and knowing, to an inch or so, how deep the coal lies, as well as the quality and thickness of the stratum bored. The boring notes of collieries are the grand arcana of the coal-mining trade, which the owners sometimes dislike to discover to the prying eyes of the philosopher. They have, however, been occasionally exhibited, which gives us an opportunity of laying before our readers an account of what relates to the boring of two of the principal collieries in the neighbourhood of Newcastle.

Section of the Strata South of the Main Dike in MONTAGUE MAIN Colliery, 3½ Miles above Newcastle.—The Numbers in the first column on the left-hand form an Index, from which it will be immediately perceived, where the same strata occur; the second column contains the number of the strata, the third the names of each, and the fourth, or numeral columns, express the thickness of each stratum in Fathoms, Yards, Feet, and Inches.

		Particulars of the Strata.	Thickness of each Stratum. Fa.	Yds.	Ft.	In.
0	1	Soil	0	0	1	0
0	2	Clay	2	0	2	0
1	3	White post	0	0	2	6
0	4	Coal	0	0	0	4
2	5	Black metal stone	0	1	0	2
3	6	Grey post	1	1	2	0
4	7	Blue metal stone	2	1	1	0
3	8	Grey post	2	0	0	0
1	9	Strong white post	2	1	0	0
3	10	Grey post	0	1	1	0
5	11	White post with black metal partings	5	0	0	0
3	12	Grey post	0	0	1	4
6	13	Brown post with coal pipes	0	1	1	8
1	14	White post	2	1	0	0
7	15	Ditto mixed with whin	0	1	0	0
0	16	Coal	0	0	0	6
2	17	Black metal stone	4	1	0	0
8	18	Grey metal stone	4	2	0	0
9	19	Brown post with skanny partings	0	1	1	0
0	20	Coal	0	0	0	9
8	21	Grey metal stone	1	1	2	10
10	22	Coal } BENWELL MAIN	0	0	1	9
11	23	Band } BENWELL MAIN	0	0	0	6
10	24	Coal } BENWELL MAIN	0	1	0	0
8	25	Grey metal stone	0	1	1	0
1	26	Strong white post	2	1	1	0
12	27	Whin	0	0	2	0
1	28	White post	1	0	2	0
0	29	Coal	0	0	1	8
2	30	Black metal stone	1	1	0	0
1	31	White post	3	0	0	0
2	32	Black metal stone	4	1	0	0
8	33	Grey ditto	5	0	2	4
13	34	Ditto post with whin girdles	2	1	0	0
1	35	Strong white post	6	0	2	0
8	36	Grey metal stone	3	0	2	0
0	37	Coal	0	0	0	8
14	38	Post girdle	0	0	2	0
8	39	Grey metal stone	1	0	1	0
15	40	COAL. BEAUMONT SEAM	0	1	0	4
16	41	Strong white thil.	0	1	0	7
1	42	Ditto do. post	2	0	0	4
1	42	Coal	0	0	1	6
17	44	Black thill	0	0	2	4
8	45	Grey metal stone	0	0	1	2
3	46	Ditto post	0	0	2	0
8	47	Ditto metal stone	0	0	2	10
1	48	Strong white post	0	1	0	4
0	49	Coal	0	0	1	3
2	50	Black metal stone	1	0	2	4
1	51	White post	0	0	1	8
18	52	Blue metal stone with post girdles	1	0	0	0
19	53	White post with whin gridles	2	0	1	9
2	54	Black metal stone	0	0	1	5
3	55	Grey post	0	0	1	2
4	56	Blue metal stone	0	1	0	0
1	57	Strong white post	0	0	1	3
4	58	Blue metal stone	1	0	2	1
0	59	Coal	0	0	0	8
17	60	Black thill	0	1	0	4
18	61	Blue metal stone with post girdles	1	0	1	0
3	62	Grey post	0	1	0	0
1	63	Strong white post	3	1	2	6
2	64	Black metal stone	0	0	0	1
20	65	COAL, LOW MAIN	0	0	2	11
8	66	Grey metal stone	4	1	0	0
1	67	White post	2	1	0	0
21	68	Grey metal stone with post girdles	1	0	0	0
19	69	White post with whin girdles	3	0	1	6
21	70	Grey metal stone with post do.	0	1	1	0
22	71	COAL, LOW LOW MAIN	0	0	2	10
8	72	Grey metal stone	0	1	2	0
1	73	White post	0	0	2	0
8	74	Grey metal stone	0	0	1	8
2	75	Black metal do.	0	0	0	10
8	76	Grey do. do.	1	0	2	6
3	77	Ditto post	1	0	0	6
19	78	Strong white post with whin girdles	3	1	1	8
8	79	Grey metal stone	3	0	2	6
3	80	Ditto post	0	0	2	0
1	81	White post	0	1	2	0
8	82	Grey metal stone	0	0	1	0
0	83	Coal	0	0	0	6
8	84	Grey metal stone	0	0	1	0
21	85	Ditto with post girdles	3	0	2	2
0	86	Coal	0	0	0	5
8	87	Grey metal stone	0	0	0	4
3	88	Ditto post	1	0	1	6
7	89	White do. mixed with whin	2	1	0	4
8	90	Grey metal stone	0	0	1	0
0	91	Coal	0	0	0	3
2	92	Grey metal stone with post girdles	1	0	0	6
19	93	Strong white post with whin do.	0	1	2	5
			122	1	2	3

Section of the Strata of the Low Main Coal at Saint Anthony's Colliery, three Miles below Newcastle.

Thickness of each Stratum.

		Particulars of the Strata.	Fa.	Yds.	Ft.	In.
0		Soil	0			0
0		Clay	4			0
1		Brown post	12			0
0		Coal	0			6
2		Blue metal stone	2			0
3		White girdles	2			0
0		Coal	0			8
4		White and grey post	6			0
5	9	Soft blue metal stone	5			0
0	10	Coal	0			6
6	11	White post girdles	3			0
7	12	Whin	1			6
8	13	Strong white post	3			0
0	14	Coal	0			0
9	15	Soft blue thill	1			0
10	16	Soft girdles mixed with whin	3			0
0	17	Coal	0			6
11	18	Blue and black stone	3			0
0	19	Coal	0			8
8	20	Strong white post	1			0
12	21	Grey metal stone	1			0
0	22	Coal	0			8
13	23	Grey post mixed with whin	4			0
14	24	Ditto girdles	3			0
15	25	Blue and black stone	2			0
0	26	Coal	0			0
12	27	Grey metal stone	2			0
8	28	Strong white post	6			0
16	29	Black metal stone with hard girdles	3			0
17	30	Coal, High Main	1			0
			76	0	0	0
18	31	Grey metal			0	0
6	32	Post girdles			2	0
5	33	Blue metal			1	0
14	34	Girdles	0	0	1	2
2	35	Blue metal stone	5	0	0	0
8	36	Post	0	0	1	0
2	37	Blue metal stone	3	0	0	0
19	38	Whin and blue metal	0	0	1	6
8	39	Strong white post	3	1		
1	40	Brown post with water	0	0	0	7
20	41	Blue metal stone with grey girdles	2	0	2	0
0	42	Coal	0	1	1	0
2	43	Blue metal stone	3	0	0	3
8	44	White post	0	1	1	0
0	45	Coal	0	0	0	6
21	46	Strong grey metal with post girdles	2	0	0	6
8	47	Ditto white post	1	0		0
7	48	Whin	0	0		0
2	49	Blue metal stone	1	0		7
21	50	Grey ditto with post girdles	2	1		5
22	51	Blue do. whin do.	1	1		3
0	52	Coal	0	0		6
23	53	Blue grey metal	0	1	0	8
8	54	White post	2	0	0	7
24	55	Ditto mixed with whin	2	0	0	0
8	56	White post	1	0	2	0
25	57	Dark blue metal and coal	0	0	2	2
26	58	Grey metal stone and girdles	2	0	2	0
24	59	White post mixed with whin	3	0	0	7
7	60	Whin	0	0	1	0
24	61	White post mixed with whin	1	0	0	6
12	62	Dark grey metal stone	0	1	0	3
0	63	Coal	0	1	0	6
27	64	Grey metal with whin girdles	1	1	1	10
21	65	Ditto with girdles	1	1	0	0
0	67	Coal	0	1	0	2
23	68	Blue and grey metal	0	1	1	0
8	66	White post	0	1	0	0
0	69	Coal	0	0	0	9
23	70	Blue and grey metal	2	0	0	0
24	71	White post mixed with whin	0	1	1	6
18	72	Grey metal	1	0	0	6
21	73	Ditto with girdles	1	0	0	9
28	74	Coal, Low Main	1	0	0	6
			135	0	1	6

From the foregoing sections will be seen, the various sorts of substances through which the miner, near Newcastle, has to pass, before he comes to the object of his pursuit: these substances we may divide into six different classes, of each of which we will give an account in their order.

1st. Whin-stone; the strata thus named are the hardest of all others, so that angular pieces of it will cut glass. It exhibits, by fracture, the appearance of large grains of sand, half vitrified. It can scarcely be wrought, or broken in pieces by common tools, without the assistance of gunpowder; it decays a little by being exposed to the atmosphere, leaving a brown powder; in the fire it cracks, and turns reddish-brown. Each stratum is commonly homogeneous in substance and colour; the most common of which are black or dark blue, yet there are others of it ash-coloured and light brown.

2d. Post-stone, is a free stone of the hardest kind, of a very fine texture, and when broken, appears composed of the finest sand. It is commonly found in a homogeneous mass, though variegated in colour, and is not subject to injury from exposure to weather: there are four varieties of this stone; 1st. The white-post, which, in appearance, is like Portland-stone, but considerably harder. This is sometimes found having brown, red, or black spots. 2d. Grey-post, which has the appearance of a mixture of fine black and white sand; it is often variegated with brown and black streaks, the last mentioned look like small clouds composed of particles of coal. 3d. Brown or yellow post is often met with of different degrees of colour, most frequently that of light ochre or yellow sand. It is as hard as the others, and sometimes has black and white streaks. 4th. Red-post is generally of a dull red colour. It is often streaked with white or black, but is rarely met with. All these lie in strata of different thicknesses, but commonly thicker than any other strata. They are separated from each other by small partings of coal, of sand, or of soft matters of different colours, which are very distinguishable.

3d. Sand-stone; this is a free stone of a coarser texture than the above; it is easily pervious to water, and when broken, is of a coarse sandy texture. It is friable, and readily moulders to sand when exposed to the air and rain. It has frequently white shining spangles, or plates of mica, in it, and pebbles, or other small nodulous stones inclosed in its mass; of this there are two kinds, distinguished by their colours grey

and brown. It is found in confiderable thicknefs with but few partings, which are fandy or foft. It is fometimes in layers as thin as the common grey flate.

4th. Metal-ftone; this is a tolerably hard ftratum, next in point of hardnefs to fand-ftone, folid, compact, of confiderable weight, of an argillaceous fubftance, interfperfed with nodules or balls of iron ore, and yellow or white pyrites. The furfaces of its ftrata are hard, polifhed, and fmooth. When broken, it has a dull dufky appearance, is of a fine texture, like hard, dried clay mixed with particles of coal. Though hard in the mines like the fand-ftone, it moulders when expofed to the action of the air. Its colour varies from black to light brown or grey; it lies in ftrata of various thicknefs.

5th. Shiver; this ftratum is more frequently met with in collieries than any other; it is known to the miners under the names of black fhiver, black metal, or bl-as; the black is the moft common, it is fofter than metal ftone, and, in the mine, is rather a tough than a hard fubftance. It is eafily feparable by the multitude of its partings. It breaks into long fmall pieces when ftruck with force, which, on examination, prefent the figures of fmall irregular rhomboids, each of which has a polifhed glaffy furface; when broken acrofs the grain, it exhibits a dry laminated texture, like exceedingly fine clay. It is very friable, feels to the touch like an unctuous fubftance, and diffolves in air or water to a fine black clay; and, like the laft mentioned, it fometimes contains nodules of iron ftone, often even beds of iron-ftone are found in it. The colour of the fhiver is not confined to black; it difcovers brown, dun, and grey colours, and a variety of fhades according to the proportions of each. Its ftrata are parted from each other by lamina of fpar-coal, or other matter; as may be feen by the foregoing fection.

Many of thefe ftrata are confiderably thick, being frequently found from 100 to 200 feet in depth, or upwards, of nearly the fame kind of matter throughout, whilft others again are of the leaft imaginable thicknefs. They are all divided or parted from each other, either by an even, fmooth, polifhed furface, or with a very thin lamina of foft, dufty matter between them, called the parting, by which means they are eafily feparated; yet though the furfaces are fometimes fo clofely joined together, that it is with difficulty they can be feparated, which is called a bad parting, they are never known to be in the flighteft degree intermingled.

There are befides this principal divifion or parting, fecondary ones alfo laterally, but thefe are not fo ftrong or vifible, and are only met with, where the texture is not of a uniform hardnefs or colour through the whole body of the ftrata. In almoft every ftratum there are other divifions called backs, which crofs the former longitudinally, and cut the whole ftratum through its two furfaces; thefe are again croffed by others, called cutters, running either in an oblique or perpendicular direction, and which cut the ftratum through its two furfaces, and, together with the other partings, divide it into various figures. The fofter kind of ftrata has in general more backs and cutters than the harder ones, which fometimes have thin partitions of dufty or foft matter, but like the partings are fometimes without any. Whenever the ftrata lie regularly they are thus divided, and generally extend in this manner through a large extent of country, though it is often otherwife, for that regularity is frequently interrupted, and the ftrata difordered by various chafms, breaks, or fiffures, which are called *dikes*, *hitches*, and *troubles*, according to their dimenfions, and the matters with which they are filled; firft,

Dikes, or *faults*, are fiffures of the largeft kind, which feem to be cracks, or breaks, of the folid ftrata, occafioned by one part of them being broken away and fallen from the other. They generally run in a ftraight line for a confiderable length, and penetrate from the furface to the greateft depth ever yet tried, in a direction fometimes perpendicular, and fometimes oblique, to the horizon, in which cafe they are faid to hade or underlay. The fame kind of ftrata are found lying upon each other in the fame order, but the whole of them are fometimes greatly elevated or depreffed on the one fide of the dike or on the other. Thefe fiffures are frequently two or three feet wide, and at other times many fathoms. If the fiffure or dike be of any confiderable width, it is generally filled with heterogeneous matter, different from that of the folid ftrata on each fide of it; fometimes with clay, gravel, or fand, fometimes with a confufed mafs of different kinds of ftone lying edge-ways, and at others with a folid body of free-ftone or even whin-ftone. When the fiffure is of no great width, fuppofe two or three feet, it is then ufually filled with a confufed mixture of the different matters which compofe the adjoining ftrata, confolidated into one mafs. If the dike runs or ftretches north and fouth, and the fame kind of ftrata are found on the eaft fide of the dike, in a fituation with refpect to the horizon, 10 or 20 fathoms lower on the other fide, it is then faid to be a dip dike, or down-caft dike, of 10 or 20 fathoms to the eaftward; or counting from the eaft fide, it is then faid to be a rife dike or upcaft, of fo many fathoms weftward. If the ftrata on one fide are not much higher or lower with refpect to the horizontal line, than thofe on the other, but only broken off, or removed to a certain diftance, it is then faid to be a dike of fo many fathoms deep, and from the matter contained between the two fides, it is denominated a clay, a ftone dike, &c. There are fome, though they are not often met with in the coal countries, whofe cavities are filled with fpar, ores of iron, lead, or other metallic or mineral matters; and it is pretty well known, that all metallic veins are nothing elfe than what in the coal countries are called dikes. It generally happens, that to a confiderable diftance on each fide of the dike, all the ftrata are in a kind of fhattered condition, very tender, eafily pervious to water, and debafed greatly in their quality, and in their inclination to the horizon often altered.

2dly. A *hitch* is only a dike of fmaller degree, by which the ftrata on one fide are not elevated or feparated from thofe on the other more than a fathom. Thefe hitches are denominated in the fame manner as dikes, according to the number of feet which they elevate or deprefs the ftrata.

3dly. *Troubles* or bends may be called dikes of the fmalleft degree, for they are not a real breach, but only a tendency towards it. The ftrata are generally altered by a trouble or bend from their regular direction to a different one. When the regular courfe of the ftrata is nearly level, a trouble will caufe a confiderable afcent or defcent; where they have, in their regular fituation, a certain degree of afcent and defcent, a trouble either increafes or alters it to a contrary direction; and a trouble has thefe effects upon the adjoining ftrata in common with dikes, that it greatly debafes them from their original qualities; the partings are feparated; the backs and cutters disjoined, and their regularity difordered; the original cubic and prifmatic figures, of which the ftrata are compofed, are broken, the diflocation filled with heterogeneous matter, and the whole ftrata are reduced to a fofter and more friable ftate.

Notwithstanding that the dikes and hitches, or faults, as they are as generally called, are filled with extraneous matters, in a considerable degree of disorder, yet there generally is a *leading*, as the miners call it, or streak of imperfect and mixed coal, which leads or directs to the vein on the other side of the fault, whether the same be higher or lower, and by which they are in a considerable degree directed, in cutting the fault to recover their vein; in very considerable faults, like that on the north of N castle, which drops the strata 540 feet, it is not probable that any leading can be traced. In the coal-mines near Bath, there is a fault which has altered the level of the same vein of coals, much more than in the above case.

By the sinking of the shaft, which is a narrow, perpendicular passage, a communication is opened with the various strata above-mentioned, and the different veins of coal. The strata of this fossil are seldom or never found to lie in a true horizontal situation, but generally have an inclination or descent, called, as before noticed, the *dip*, to some particular part of the horizon. If this inclination be to the east, it is called the east dip and a west rise, and according to the point of the compass, to which the dip lies, is it denominated. This inclination, or dip of the strata, is found every where; in some places it varies very little from the level, in others very considerably, even so much as to be nearly in a perpendicular direction; but whatever degree of inclination the strata have to the horizon, if not interrupted by dikes, hitches, or troubles, they are always found to lie in the regular manner first mentioned. They generally continue upon one uniform dip, until they are broken or disordered by any of the above interruptions. Wallis, in his "History of Northumberland," tells us, that the strata in that part of the island generally rise to the north-west and dip to the south-east. Dr. Stukely, in his "Itin. Curios." 1725, says, that some of the coal-works in the same country dip full east; but it is plain, he adds, that south-east is the natural dip. As those at Whitehaven, inclining south-west, receive, he supposes, a counter-bias, as being on the west side of the island; he further observes, that the principal dip is to the south-east; yet in this country dips in various directions, as the fall of valles, or beds of rivers, as well as the causes above-mentioned, occasionally influence its primary bent. See *Geology*, *Plate* I. *fig.* 1. where *aa* is intended to represent the vegetable mould or alluvial matters deposited on the surface of the regular strata, represented by *b*, *c*, *d*, *e*, &c. on the left-hand side of the figure. AA, and BB, are intended to show the dikes, by which the same are disjointed, depressed, or elevated, as before described; and where CC shows a hitch or smaller dike; DD, EE, FF, and GG, are the representations of troubles or bends of the strata.

Such are the usual dispositions of the strata; two principal difficulties are met with in the descent, the first is in keeping out quick-sands where they occur, and the second to keep the shaft so dry as to allow the men to work. A quick-sand is kept out by a process called "tubbing," that is forming a circle in the inside of the pit where the sand bed is, with staves of oak, each piece being shod with a sharp piece of iron; these are driven through the stratum of sand, so closely joined that no water can penetrate, and are kept in their situation by internal hoops or kirbs at certain distances; the water is drawn out now generally by a steam-engine and pump. See STEAM ENGINE, PUMP, *Pressure* ENGINE, *Bucket* ENGINE.

Through a large district of South Wales, their highly valuable veins of coals, of which an account was lately presented by Mr. Edward Martin to the Royal Society (and published in the Philosophical Transactions for 1806, p. 342, &c.) are gained at comparatively trifling expences, compared with most of the Newcastle pits; the depth of the vallies and heights of the hills in that part of the country, allowing several successive and thick veins of coals to be worked by tunnels into the hill above the level of the rivers, or springs of water, in the vallies; and the coals, and the valuable iron ore which also abounds, are let down into the boats on the canal tunnels, or as loading for tram-waggons in the tunnels below; through which they are conveyed to open day, and thence to the iron-works or place of shipping: of several of these curious works in South Wales we have given concise accounts, under the names of the particular canals, railways, &c. in our article CANAL; and we shall take occasion, as the names of them occur in our work, to give several material additions and corrections which have come to our knowledge, principally through the kindness of Mr. Martin above mentioned, since that article was put to press, so as to render the same, we hope, quite complete.

In the environs of Glasgow there are considerable coal-mines of excellent quality, which are also worked at an easy expence; they are found under beds of quartzose freestone, which in some mines are more than 140 feet thick; it adheres to the freestone, without any intermedium. The coal appears at the depth of 30 feet from the surface, in scattered lines running in an irregular manner through the midst of the freestone; then follow beds of the same stone without the least vestige of coal, but as the beds descend, the coal reappears in small straggling and interrupted seams from three to four inches thick; these are again succeeded by an unmixed mass of freestone, which falls through a depth of more than 40 feet, and terminates in solid and continued beds of coal. It is much to be regretted that the operation of boring is held in so little estimation in Scotland, but the reason is very obvious; in England it is made a distinct trade, and is conducted by men of information, who have been regularly brought up to the business: in Scotland it is effected by any common workmen about the pits, possessing neither information nor experience, and their accounts are consequently so confused, imperfect, and equivocal, as to merit no confidence whatever.

The great and universally felt importance of its veins of coals to this country, makes us again regret our inability, at present, to lay before our readers, any more than a few of the principles, of the modern and yet unpublished discoveries of Mr. William Smith, on this and other subjects connected with the stratification of the British islands (see our articles *Structure of the* EARTH and STRATIFICATION.) It is confessedly of the first importance, either to the inhabitants of a district in general, or to the owners of the soil in particular, to be able to detect and work such veins of coal, as may exist under their soil; and hence we find on inquiry in the neighbourhood, that almost every common, moor, heath, or piece of bad land, in parts where coals are scarce, have at one time or other been reported by ignorant coal-finders to contain coal: how many times, for instance, have our grandmothers and nurses, repeating their stories, told us, that plenty of coals might be dug at Blackheath, near Woolwich, and on other commons near London, if government had not prohibited their being dug, for encouraging the nursery of seamen, &c. Our inquiries, and those of Mr. Smith, have brought to light hundreds of instances, where borings and sinkings for coals have been undertaken in such situations, and on such advice, in the southern and eastern parts of England, attended with heavy, and sometimes almost ruinous, expences to the parties, though a source of profit to the pretended coal finders, who, or some of their never-failing race of successors, equally sapient, have in many instances been able to return to the same spot

or neighbourhood, and persuade a new proprietor to act again the same farce, and squander his money on an unattainable object; for such, we can without hesitation pronounce, the publication of Mr. Smith's map and sections of England will prove it to be. This gentleman, more than 15 years ago ascertained, by an actual examination of the country, that the stratum on which London stands, is the highest but one (the Bagshot-Heath Sand) in the British series of strata, and that whether we proceed from London directly for the Newcastle coal mines, in a direction not greatly to the west of a north point, or to those in Somersetshire, near Bath, lying in an easterly direction, or rather south of it, from the metropolis; or whether we travel thence to the nearest coal mine, lying in any intermediate direction, as in the counties of Durham, Yorkshire, Nottinghamshire, Leicestershire, Warwickshire, Gloucestershire, &c.; on a careful examination we shall find, the very same succession of strata occurring upon the surface, and may easily satisfy ourselves, by an examination of the quarries, pits, and even of the hollow roads and ditches, which are every where to be found, of the identity in the nature of the various stratified matters, as sand, chalk, marle, clay, limestone, &c.; and of the exact occurrence of each in the same order, as we proceed outwards from the metropolis. A more particular examination will next satisfy us, that these appearances are occasioned by the several strata which we have mentioned, successively rising towards the north west, (and consequently dipping in the contrary direction) generally speaking, and ending one after another, with very curiously indented or fingered edges, after which the same stratum never occurs again: the chalk strata, for instance, will be quitted near Dunstable, in the road to Warwickshire, and never be seen afterwards on the surface, or be found sunk to in any pit or excavation during all the remainder of the journey, or even in pursuing one in the same direction, to the utmost limits of the British islands; and, though we shall, in such an examination, meet with a number of different sands, clays, and other strata, which may seem at first sight to be recurrences of the same stratum, after it has risen to the surface and ended; yet, on examining two of such more minutely, we shall find, either the strata lying in undisturbed contact with them above and below, to be different in the two cases, or their visible or chemical qualities to differ, their thicknesses to vary, or, that the same particular species of organic remains are not found imbedded, or their impressions left in one of the strata, as are observable in the other: wherever, on the contrary, these circumstances concur, they may be said to prove the identity of any stratum, at however distant points it may be compared; and for shortening our inquiries for such purpose, science happily presents us with the prospect of similar advantages, to those possessed by the botanist of the present day; who, instead of examining all the parts of a plant supposed to belong to particular genera or species, proceeds at once to examine some one or two of them, which the writings of former botanists have shown to be essential characters of that particular plant; and it is no unreasonable hope now to form, that the essential characters of each of the most remarkable and useful strata in the British series, will ere long be generally known to mineralogists, since they have become so to some particular individuals. Each particular stratum appears to us, to have formed part of one vast plane, with a slight inclination towards the south-east, or nearly, and with great extension in the directions of N.E. and S.W. in these latitudes; prior to the truly enormous violence with which the earth has since been dislocated and broken, during the formation of the dikes, faults, hitches, and troubles, which we have had occasion more particularly to mention in this article, and some greater ones, which we shall have future opportunities of mentioning, particularly that by which the whole of the land of England, south of the river Thames, has been disturbed and broken from its original position (dipping S.E.) into one, in which all the strata north of a line passing not far from Hastings, Battle, East Grinstead, Guildford, &c. have now a much greater dip, nearly at right angles thereto, or N.E.; while, on the other, or south side, they have just a contrary or S.W. dip; but with as many local deviations or partial dips in each case, as are usually to be found, and which sometimes vary, perhaps in several directions, many times in travelling a mile, and yet on the whole, the strata keep rising as above, the planes being the longest in one particular direction.

The organic remains, or exuvia of different animals, and the remains of plants, are found lodged in our strata in the greatest abundance, and, to superficial observers, appear to have no method or arrangement therein; but, on a closer examination, and taking care to notice the minuter differences in these organized remains, it will be found, that each particular kind, either alone, or mixed with one or more distinct kinds, occupies a certain thickness of strata, sometimes but an inch, or less, and sometimes many feet, but extending to the greatest distances in the plane of that stratum, and that either above or below those limits, the remains will be found to be different, or none are found; hence the layers of shells, plants, &c. become the most useful, as well as certain, criteria of the identity of strata; these often changing, where the obvious qualities of the strata appear unchanged, by which means they divide thick strata into thinner ones, and furnish us with so many more ascertained or known points in the progression of strata; which, in the confined operation of sinking a shaft or well, is of the greatest importance, but particularly so in boring, for ascertaining the strata. See Philosophical Magazine, vol. xxv. p. 45.

We have been led to enter thus far into Mr. Smith's theory of the stratification, in order to explain in this place some part of that which relates more particularly to the finding of coal; and as the mention of organic remains has, and must often again occur, we beg here to call the attention of our readers to three distinct eras observable, relating to fossil organized bodies; 1st, that period in which the animals themselves, or their exuvia, and vegetables, were quietly deposited and buried, in and among the successive depositions of strata, taking effect according to laws, apparently as uniform and extensive as those of crystallization; 2d, a period wherein the strata were ruptured, torn, and washed by mighty currents of water, and during which great quantities of the organized remains from within the strata were detached, broken, and worn, and at length left with the gravel and alluvial matters, which now cover almost every part of the surface, although, in many places, such alluvium is no thicker than what is called the vegetable mould; 3d, a period extending from the last to the present time, in which the waves of the sea on its coasts, the currents of inundated rivers, and the other operations of nature, have, though in a very limited degree, been continuing the same process of washing out, breaking, exposing, and wearing the original organized matters of the strata, those which had in the second period been deposited with the gravel and alluvium; and exposing also, in many instances, organized remains belonging to an earlier part of the present or third period; which is further distinguished, by the growth of immense beds of vegetable, or peaty matters on the surface, which have inclosed the remains of recent animals, vegetables, &c. mixed with the occasional depositions of muddy waters, to which such have, in low situations, been repeatedly subject.

When, therefore, we speak of organized remains, without

further explanation, we wish to be underftood as meaning thofe of the ftrata, of the firft era, no otherwife altered than by the gravity or chemical action of the furrounding matters; when we wifh to fpeak of the organized remains peculiar to the ftrata, but difturbed during the fecond era, we fhall, as Mr. Smith does, call them *gravel foffils*; and this, whether they bear marks of breaking and wear, or not, if they are found depofited with gravel, or among angular or worn fragments of matter near the furface, the evident effects of collifion and attrition; when we have to mention the organized foffil matters of the third era, if they appear fuch as have been depofited by water among gravel, and the depofitions of water, as above mentioned, or have been buried by the labour and works of men or animals, and undergone a mineralization, we fhall call fuch *recent foffils*, while thofe which owe their burial, and probably their change and prefervation, to vegetation, fhall be called *peat foffils*; thefe terms and diftinctions appear to us effentially neceffary for avoiding, in thefe inquiries, endlefs miftakes and abfurdities, into which former writers on this fubject have been led, for want of fuch difcriminations. When organized matters of the prefent race, are found on or near the furface of the earth unchanged, at leaft, not mineralized, they will ftill be denominated recent fhells, bones, teeth, horns, plants, &c. and will be fufficiently diftinguifhed from our recent foffils above.

A careful examination of the feveral ftrata which intervene and end, between London and any of the neareft points mentioned as coal-diftricts, will fhow thefe ftrata to be very various in their qualities, and in their thickneffes (altogether amounting to feveral hundred fathoms), with no one circumftance fo obfervable among them, as the total abfence of diftinct vegetable impreffions or remains (among their numerous animal remains,) except of wood, and which, it is obfervable, are generally, we believe we might have faid always, found in thefe upper ftrata in the feries, in cafual, detached, and broken pieces of the trunk, almoft like chips and billets, and generally with the appearance upon them of previous rottennefs and wear, from toffing or floating in water; not unfrequently alfo, this fuppofition is ftrengthened by the worm-holes with which thefe detached pieces of wood abound, particularly in the Woburn Sand ftratum, where mineralized remains of the worms or animals which perforated the wood, found below the fuller's-earth ftratum, are ftill feen occupying the holes in the filicious wood, of which we have fpecimens now before us. The pieces of wood found in the feries above the coal, are in ftates as various as the matters of the ftrata inclofing them; in many inftances they are filicious, pyritic, or ochreous, lefs frequently, perhaps, they occur in a foft rotten ftate, fometimes like charcoal, and at others bituminized almoft to the confiftence of pitch; and thefe laft fpecimens they are, which, when accidentally accumulated, as at Bovey-Tracey, and many other places, on the out-crop of the Purbeck pipe-clay ftratum, have been improperly denominated coal ftrata; and in Suffex, and other parts, have mifled the coal-finders, or perhaps rather their credulous employers, above alluded to.

This abfence of vegetable impreffions will be found to continue in our journey outwards from the metropolis, until a remarkable ftratum is paffed, called by the miners in Somerfetfhire the "red earth," being a very red ferruginous earth, or ftone, fomething like that on which the city of Coventry ftands: from hence, examining weftward or northward, we fhall find a material change take place, in the animal remains becoming very fcarce, and vegetable impreffions beginning to appear and increafe, among a certain feries of ftrata, called, by the miners of feveral counties, the "coal meafures," which are often remarkable for their quick and varied alternations, as the two fections of coal ftrata or meafures, which we have given in this article, will exemplify. For many fathoms together, among fome of the coal meafures, particularly in the argillaceous or coal-fhales, fcarcely a lamina of the ftrata, as thick as paper, can be fplit off, without expofing the impreffion or bituminized remains of fome plant, as mentioned hereafter, many of them highly beautiful: as thofe appearances increafe, veins of coals, or uniform ftrata of thefe bituminized vegetables, without the intervention of fhale, or earthy matters, occur; thefe are often extremely thin, and have intervening ftrata, or coal meafures, fometimes of confiderable thicknefs between them, fo that in fome of our Britifh coal-pits, 30 or more diftinct and feparate veins of coal are funk through, before the "main," or moft defirable feam of coals is reached; from which, if the pit was to be farther funk, or if we travel weftward or northward to the ending of the feveral meafures funk through, and over thofe below, we fhall at length find thefe coal-meafures end, and what the miners call "dead earth," or ftrata, as diffimilar to coal-meafures as thofe at the top of the Britifh feries, already mentioned, will be found to fucceed through a certain feries of ftrata, but then other coal-meafures will be found to occur again, &c. Thefe different fets of coal meafures traverfing the country, as now feen on Mr. Smith's map, have often been noticed by practical men, and by fome writers, under the title of "runs of coal;" and that on which Newcaftle is fituated, probably from its early and great importance in fupplying the metropolis, has been called the "great run." The firft workings of all our coal has evidently been upon their out-crop, or breaking to day, either at the ending of the ftrata, or where the former and convulfive heavings of the ftrata have left their edges bare, or nearly fo: but experience has progreffively proved, as the improvements of pumps, and machinery permitted, that the coals were better in quality, and lefs troubled, the farther they were purfued into the deep, or in the direction of the "ten o'clock fun," from their out-crop, moft generally: and thus the Newcaftle mines have been progreffively creeping nearer to the fea, and now extend to, or under it, and ftill find their coals improve; of which the Wall's End coals, brought to the London market, are an inftance: in like manner, the mines on the oppofite coaft, near Whitehaven, for working feams, which the local dip of that part occafions to defcend under the fea, have their works now extended near a mile under the ocean, at about fix hundred feet beneath its bottom. Accordingly it has occurred, that mines have been begun higher and higher up, on the feries of ftrata, called coal-meafures, and, confequently, had their pits of greater depths, and now the attempt is making at Bath-Eafton, in Somerfetfhire, of finking in matters above the red earth, in hopes of there reaching the Somerfetfhire coal-veins, hitherto not worked fo far eaftward, or into the deep, by fome miles, although fome of their mines, owing to the rapidity of the partial dips are, we believe, working at the greateft depths of any in the kingdom. An application of the principles above explained will enable any ingenious perfon to judge, whether his diftrict is likely to contain coals, at practicable mining depths; for it feems an ufelefs inquiry, whether they exift or not beyond this; for inftance, whether the vicinity of London, and the more fouth-eafterly parts of our ifland have the coal veins of the middle counties dipping under them, it can be of fmall ufe to inquire; from the immenfe number and thicknefs of the known ftrata which intervene, and contain no coals, or other very valuable matters. The very open and porous ftate of fome of thefe ftrata, the chalks (more than 50 fathoms thick) for inftance, occafion them to be fo powerfully fupplied with

water, as to render the profpect of finking even one fhaft through them at London, utterly hopelefs. Mr. Dodd, whofe fcheme for a tunnel in chalk under the Thames. at Gravefend, we have noticed in our article CANAL, has fince complained to the public, that the boring of one fmall augre hole, before his fhaft was funk, let up fo much water into it, that he was unable to penetrate more than 122 feet deep; what then was he to have expected, had he ever come to open the length of 900 yards of an 18 feet tunnel in this fame chalk? We hope to be excufed for thefe digreffions, as they tend, we think, to illuftrate the queftion, of the practicability of finding coals, through a large and important part of our ifland; and we fhall now proceed to the methods ufed in finking for coals.

The firft operation after finking the engine pit of a coal mine is the working or driving in the coal, and finking the firft coal pit; the fituation of which fhould be a little higher up the plane of the ftrata, or to the rife of the engine pit, that the water which collects may not obftruct the working of the coals when the engine ftops: yet it fhould not exceed the diftance of 30 or 40 yards, becaufe when the firft mine is to be driven a long way, it becomes both difficult and expenfive. After the pit is thus funk to the coal, the miner is to begin his work; he firft digs or undermines with his pick-axe, a light inftrument for hewing coal, (nearly in the fhape of an inftrument of the fame name ufed by paviors and gardeners) at the bottom, and on one fide, into the feam or ftratum as far as he can; he then forces down great pieces of coal by a wedge and mallet, taking care to leave, at proper intervals, pillars for fupporting the roof.

Fig. 2. in *Plate* I. reprefents the plan of the workings of a coal mine, where A A reprefents the main paffage or gangway, in the direction of the dip, and in which tram-plates or rails are now often laid, for the paffage of the trams loaded with coal to the pit or winding fhaft; B B, C C, D D, and E E, reprefent other parallel and ftraight paffages, between the pillars of coal, *a*, *b*, *c*, *d*, &c. *e*, *f*, *g*, *h*, &c. which are left for fupporting the roof and ftrata above.

The coal is often wrought in this manner to the limits of the mine; when thefe pillars, or fo many of them as can be got, are taken out by a fecond working, and the roof and other folid ftrata are permitted to fall down and fill up the excavation, often to the great and permanent injury of the furface of the land, and fometimes to canals, and other works, as particularly mentioned under our article CANAL.

If the roof and pavement are both ftrong, as well as the coal, and the pit only 30 fathoms deep, then two-thirds or three-fourths may be taken away at the firft working, and one-third or one-fourth left in pillars; if tender, it will require a larger proportion to be left, probably one-third or nearly one-half.

There is an overman, whofe office it is to go through the pit to examine the places which the men have wrought, to meafure their work, and to fee that the pit is free from inflammable vapour. There is alfo a deputy overman to fuperintend the pillars of coal that are left, and to fet up props or build walls, when the roof is loofe and threatens to fall. The bufinefs of the perfon called an "onfetter" is to hang the corves (ufually bafkets made of hazel rods) upon the rope to be drawn up the fhaft. Collieries are liable to an accident of a very dangerous nature, called a "creep" or "fit," when the pillars of coal are left fo fmall as to fail or yield under the weight of the fuperior ftrata, or when the pavement of the coal is fo foft as to permit the pillars to fink into it, which fometimes happens, by the great weight that lies upon them; in either cafe the folid ftratum above the coal falls and crufhes the pillars to pieces, and clofes up a great extent of the working, or probably the whole colliery.

Mr. Ryan, we underftand, propofes to cure the defect of a foft pavement, in the principal paffages, which are required to ftand for a long time, by forming them in the coal, of the form fhown in *fig*. 3. *Plate* I., or nearly approaching to elliptical; the tram-plates or rails *a*, *a*, in their bottoms occupying nearly the whole width in that part, with the undifturbed coal nearly or quite meeting under them: in this cafe it will be neceffary to conftruct two parallel paffages at a proper diftance, one for the going of the trams to the pit, and the other for their return. Another fatal accident to which coal-miners are fubject, in the vicinity of old workings between water-tight ftrata, arifes from the water contained in thefe artificial cavities, or fometimes in natural cavities or fiffures filled with loofe and porous matters, burfting in and fuddenly filling their works: the only fecurity againft this, is to bore an augre hole before the working as it proceeds, to prove the regular continuance of the coal. The collieries about Radftock, on the Somerfetfhire coal canal, have been fubject to this accident, on imprudently cutting through their faults, or dikes, which, as well as feveral of their intervening ftrata, are of water-tight matters.

There are two other evils to which coal mines are fubject; hydrogen gas called by the workmen, "fire-damp" by the explofion of which many lives are loft; and carbonic acid gas commonly called "choak damp," which is not fo fatal as the former. Hydrogen gas is principally generated, by the contact of pyrites with water in fome of the old workings of the collieries which have been neglected and not fufficiently ventilated: it there accumulates until difcovered by the occafional vifit of fome of the overmen, whofe office it is to examine the old workings called "waftes:" fometimes for want of due caution it caufes the death of many of the miners, being fet on fire with their lights. On thefe occafions the men throw themfelves on their faces to the ground to avoid the return of the blaft, as there is more danger to be apprehended from the vacuum formed by the total confumption of the inflammable gas, than from the effect which the fire has upon them. It rarely happens after an explofion that the men are much burnt; they fuffer more by the violent concuffion of atmofpheric air, rufhing into the workings to fill up the vacuum, than from any other caufe. After an accident of this kind, it is generally confidered dangerous to enter the pit for fome days, on which account it is to be feared many lives are loft which might have been faved by immediate affiftance. At Whitehaven and Workington, where the inflammable gas is very prevalent, the miners often work without candles, in driving their adits for ventilation, by the light of a flint mill, or of fparks produced fomewhat in the manner of a razor grinder's wheel: but the only effectual method of preventing accidents of this nature, is to pay due attention to the ftate of the old workings, and to caufe a thorough ventilation by the methods ufually adopted, which are the following: the air is put in motion by means of a large furnace placed near the edge of one of the fhafts inclofed in a covered building from which is a tube defcending into the pit. The heated air, thus afcending through the chimney, is fucceeded by cold from the fhaft, which in its turn is replaced from the loweft part of the mine. The whole is thus fucceffively removed, and its place is fupplied by air which finds its way from above, through another communicating fhaft open to the day. The certainty of this operation has evidently no dependence on the depth of the mine, its extent, or its form. The brifk current thus produced below, naturally takes the moft direct courfe betwixt the two fhafts. The ventilation on each fide is therefore accomplifhed, by

means of a continued communication formed betwixt the two shafts in any required direction, by opening the proper avenues, and closing all others. A continued current is sometimes made to pass in this manner for twelve or eighteen miles, see *fig.* 4. *Plate* I. where S represents the shaft, and A the adit or working of a mine which is subject to damp or foul air; *a a a* is a close pipe, leading from the part most affected to the surface of the ground, and there entering the lower part of a furnace, F, and ascending through the fire therein, by the heat of which a current of air is constantly thrown out of the upper end of the pipe: this method is applicable, and very necessary, where particular and distant parts of the mine require ventilation; because by this means fresh air can be made to descend down the same shaft, and along the adit through which the pipe and furnace cause the foul air to ascend; for the more general ventilation of coal-mines, and where fresh air can be supplied by other shafts, as it generally can in mines at work, by means of the winding shaft, the water-shaft or engine pit, or both, a simpler mode is adopted, as at Worsley mine, on the duke of Bridgewater's canal, and other places, shown in *fig.* 5. where S represents the air or ventilation shaft, having a common roll and winch-handle erected over it, from which a cage or iron basket, *c*, is suspended by a chain, and in which a large fire of coals is constantly kept burning, some yards below the surface of the ground; the winch-handle is made use of for drawing the fire to the surface as often as the same wants replenishing.

Choak damp is rarely attended with any ill effects, and is easily discovered by its extinguishing a candle. The safest method of exploring collieries subject to this evil, is to walk as erect as the workings will allow; for choak damp being heavier than atmospheric air, occupies, of course, the lower part of the mine. It is more difficult to exhaust this gas by ventilation than fire damp, as the latter ascends, from its being lighter than atmospheric air, whilst the other, by its gravity, is forced upwards with great difficulty.

It is not exactly determined by what means choak damp is generated in coal mines, but it is generally supposed to proceed from the putrefaction of vegetable substances.

After the operation of "hewing," or digging, is performed, the coals are brought to the bottom of the pit, in corves or baskets, either drawn along the ground in the manner of a sledge, or upon a small rail or train road as they are called in Shropshire, hooked on to a chain, and drawn or wound up by a rope to the surface. This is often effected by a machine called a gin, wrought by horses. Of these winding machines there are various kinds; some wrought by water, others by the fire engine; either of the last named, are only convenient in some particular situations; that wrought by horses is therefore in most general use. There are, besides, a sort of gins called "whim gins," and another known by the name of "macaroni gins." In the whim gin the ropes run upon two wheel-pullies over the shaft, the roller is at some distance, and the circular track of the horses is not round the shaft. See our article *Mine* WINDING *Engine*, and *Apparatus*. To receive the coals, there are two "banksmen," who take off the corves at the top of the pit, and empty, or, as the workmen call it, "teem" them. The coals, by teeming, are discharged into waggons, by means of a grated spout which allows the small coals to go through it, whilst the large pass into the waggon. Boys or women attend to throw aside the pyrites, or, as they are technically called, "brasses," or in other places, "slates," which are sold to the copperas manufacturers. See COPPERAS.

The coal-waggon has been already shortly described under our article CANAL; and for a fuller account, we refer to WAGGON. Our account of the waggon-ways, and rail-ways, also occurs under the article CANAL; and for other particulars relating to the conveyance of coals from the mines to the wharfs and vessels: See WAGGON, RAILWAY, and STEATH.

Having thus given a description of coal-mines, we shall give an account of a visitation to a pit. That in which the best view is gained, and which can be entered with the greatest ease and safety, is in the vicinity of Newcastle, *viz.* East Kenton colliery, the property of Messrs. Knowsley and Chapman. Having previously obtained permission of a viewer, or some other person concerned in the colliery, a small hand lanthorn must be provided, a light being necessary for each person. It is also advisable to take a change of dress, at least of upper cloaths; strong boots to keep the feet dry, and an old hat. Being thus prepared, proceed to the steath, which is by the river side, about four miles above Newcastle, a pleasant excursion by water. When there, some of the men, who have been apprized of your coming, will assist in seating you on a set of small empty coal waggons, capable of containing two persons each, seven of which are drawn along a rail-way by one horse. As soon as you are placed, with your candles lighted, you set off at full speed, with a boy in the first waggon, for a charioteer, into a tunnel, or subterraneous passage six feet high, about the same breadth, and three miles in length. It is particularly necessary to guard against putting your hands suddenly out of the waggon, as the tunnel, in most places, is only wide enough to admit the waggon and horses, and you are of course by doing so in danger of receiving an injury; but by sitting quietly, you ascend very smoothly, till you arrive at the place where the men are at work. At your first entrance into the tunnel you are struck with the noise of the waggons, which, being fastened with chains to each other, and going sometimes at the rate of ten miles an hour, make a sound resembling thunder. The passage is in general hewn out of solid rock, composed of metal stone, a sort of schistus. Where there is not rock, it is arched with brick or stone. The water from the pit runs down by the side of the rail-way to the river Tyne.

At intervals there are double rail-ways; and where you come to one of these your driver stops his horse, and a dead silence ensues; he then calls aloud, and listens to hear if any loaded waggons are coming down, that they may there pass each other; when he is past, your driver renews his speed, until he reaches the next interval, when he repeats his call, and should no answer be heard in return, he proceeds. If, by the negligence of the boys, the waggons should meet where there is no double rail-way, the boy with the empty waggon unlooses his horse, which is taught to turn round, and force the waggons back with its breast, until they reach the double part, where they can pass each other.

On the sides of the tunnel you will observe several fungi of a pure white, which, by the heat of your hand, or exposure to the open atmosphere, dissolve into water. The air up the tunnel is cold, but perfectly pure, but as you approach the workings a considerable degree of warmth is felt. You alight from your waggons in order to view the different operations to which your guide will conduct you.

In the upper seam or stratum, the coal is not much wrought on account of its inferior quality. Here you will see the stables for the horses, the steam-engine for raising the coals from the lower seam, and the ventilating furnace, by which the impure vapours are drawn off. Here you will also be shown, on the roof of one of the lateral openings of

this level, a variety of curious specimens of plants, somewhat like grasses, ferns, vetches, &c. impressed upon a sort of blue slaty stone; the different plants are remarkably distinct from each other. There is also in one part the trunk of a tree, many blocks of which have been taken out to make seats in a neighbouring garden; as far as the stone has been cut, the tree has been traced even to its smallest branches, and the roughness of the bark is still preserved in the stone: the whole of this stratum is one uninterrupted continuation of these impressions of vegetables: it is nearly horizontal, and is 112 yards from the surface.

In East Kenton colliery, there are three shafts or perpendicular openings, for raising the coals. The first is the pit at the day, near the village of Kenton: it is circular, 56 fathoms deep, and at present only used for delivering coals for sale at Newcastle. The coals are drawn up in baskets. The bottom of this pit is on a line with the rail-way from the river. The second shaft is eighteen and a half fathoms deep, and at a short distance from the bottom of the first. It is square, and just admits the waggons, which are drawn up and let down by the steam-engine. The third shaft is only 7 fathoms deep. After having examined the works, you may be drawn up to the surface by the first shaft in a basket in about two minutes, in which space of time you will have ascended 56 fathoms. But should this mode of conveyance not be approved of, you may return again by the tunnel. Brand's History of Newcastle. Com. Magazine. Dr. Black's Lectures. Wallace's Northumberland. Pennant's Tour. St. Fond's Travels. Picture of Newcastle. Papers of the Literary and Philosophical Society of Newcastle upon-Tyne. Philosophical Transactions.

Coal-*balls*, balls made of coal and clay, or slack, for firing. These balls are made with ⅓ of clay, without sand or gravel, and ⅔ of *coal-dust*, or *culm*, well mixed, and formed either into round balls or into bricks. This coal-dust being the refuse of the mine, makes this sort of firing cheap. See Phil. Trans. N° 460 sect. 3. See *Patent* Coal.

Coal *bushel*. The measure directed to be used in London and other places for retailing coals, is different from the Winchester bushel for corn, or malt bushel, 18½ inches wide, and 8 inches deep, containing 2150.42 cubic inches, described under our article Bushel. By the act of 12 Anne, the coal-bushel is directed to be round, with an even bottom, and to be 19½ inches diameter, from outside to outside, capable of containing one Winchester bushel and one quart of water; of which a standard is to be kept in the exchequer, and 36 of such bushels, heaped up, are to make one chaldron. By the act 43 Geo. III. the coal-bushel was directed to be heaped up in the form of a cone, but the exact height, or proportion thereof, to the base or top of the bushel (19½ inches) not being fixed in this act, the principal land coal-meters have, from careful and long continued observations of the custom or practice of measuring coals, fixed the height of the cone at 7 inches above the top of the bushel; this we learn from Mr. Robert Vazie, a gentleman who has laudably taken much pains, in endeavouring to introduce a bow-gage to coal-bushels, nearly similar to the bail or handle of a water-pail, which should at all times, by being lifted up and swept over the bushel, determine the proper quantity of the heaped part, which is now left to the discretion of the fillers, subject to the inattention or partiality of the meter, who is, or ought to be, standing by. According to these data, the content of the coal-bushel itself (= $1\frac{1}{32}$ corn bushel, as above) will be 2217.62 cubic inches, its depth inside varying, from about 8 to 9 inches, according to the thickness of the wood in the sides, it being the outside diameter which is fixed by law, on account of the heaping up.

A cone of 19½ inches diameter, and 7 inches high, will contain 696.8482 cubic inches, and therefore 2914.47 cubic inches, will be very nearly the cubic content of a heaped bushel of coals, = 1.6866 cubic feet, = .062467 cubic yards, = 5.866565 cubic links, = .477126 steres or new wood measures of France, = $\frac{1}{36}$ chaldron, = 4 coal pecks, = 1.3553 malt, or Winchester bushels struck. From the above calculations, our readers will see, what relation the coal bushel bears to other measures. By the late acts for regulating the delivery of coals in and near the metropolis, every waggon or cart used in delivering of coals, is required to have a lawful bushel with it, edged with iron, to prevent wear, and sealed; and using others or altering such bushels, incurs a forfeiture of 50*l.*

Coal, *Cannel*, or *Candle*. See Coal *Supra* and Ampelites.

Coal *Canal*, or *Somersetshire Coal Canal*, commences in the *Kennet* and *Avon* canal, about 3½ miles above the city of Bath, and proceeds S.W. in two branches, with rail-way extensions to the collieries N.E. of Mendip hills. See Canal.

Coal-*fish*, in *Ichthyology*. See Gadus *Carbonarius*.

Coal-*island*, in *Geography*, a village in the county of Tyrone, Ireland, where the coal works are carried on with tolerable success. In 1800, there were five pits working industriously, and the works were not much impeded by water. There is, however, great want of encouragement; and the canal, which was made at the public expence, to the Tyrone collieries called Blackwater, has been so much neglected, that it is choaked up with mud and weeds. Coal-island is about 3 miles W. from Lough-Neagh, and 4 N. from Dungannon. M'Evoy's Account of Tyrone. See Canal.

Coal *Measures*, a term among miners, for the strata most frequently alternating with beds of coal; these often consist of argillaceous shale, and contain numerous impressions of vegetables upon them, of which there was a very curious collection in the late sir Ashton Lever's museum. See our article Coal *Supra*.

Coal *Measuring*. In the pool or port of London, coals are measured out of the ship into the barges, or lighters, in a vessel or low tub, called a vat, holding nine bushels (see Vat), which is heaped up by the porters who fill, until the sworn meter, who is always in attendance, is satisfied with the justice of the measure, and directs the vat to be emptied over the ship's side into the room of the barge, &c. below. Out of these barges, &c. the coals are again measured by a standard coal bushel (see Coal-*bushel*), in the presence of another sworn meter, called a land meter, and are emptied out of the bushel into sacks, for delivery to the buyers; a few years ago, this last process was improved as follows:

Plate XIV. of *Mechanics*, represents a machine for measuring coals, for which Messrs. Simeon and Thompson took out a patent in the year 1803. The machine, from which the drawing is taken, was erected in 1803 at the Red-cross coal wharf, near London bridge, and has been at work ever since with great success near the water-works. It is erected before the wall of the coal warehouse, and communicates with the second floor, by a large opening in the wall. The barges, containing the coals, are brought under the wall of the warehouse, which is by the water-side; they are filled into buckets, and then drawn up by a machine into the house, where they are emptied into a wheel-barrow, and thus conveyed to the stage, A, *fig.* 1, in the floor of which

the buſhels, B, B, B, are placed; theſe buſhels are of caſt-iron, of the dimenſion directed by act of parliament; they have moveable bottoms, opening downwards on hinges toward the wall of the houſe, and are ſhut by a chain, which is faſtened to the bottom, oppoſite the hinges, and comes up through a tube, *a*; the other end of the chain goes over, and is faſtened to a wheel of caſt-iron, E, mounted on a ſhaft, which carries ſimilar wheels for the other two buſhels; it turns on a pivot in the wall, F, at one end, and on another, working in a collar, ſupported in the wainſcoting, G, which forms the other end of the room; the ſhaft projects ſome diſtance through this partition, and has a wheel, H, fixed on it, round which a rope, I K, paſſes; the end, K, of this rope has a ring tied to it, which is hooked on a pin in the wall, which pin is adjuſtable by a ſcrew, as ſhown in *fig.* 2, ſo that when the ring is hooked on it, the bottoms of the buſhels ſhall be cloſe ſhut; *b d*, *fig.* 2, is an iron frame ſcrewed to the wall, in which a ſquare piece of iron, *e*, carrying the pin (on which the ring is hooked) ſlides; *f* is a ſcrew turning in the frame, and paſſing through the piece *e*, which is tapped, ſo that by turning the ſcrew by a winch, put on the ſquare at its upper end, the pin can be raiſed or lowered.

The chains, D, *fig.* 1, have each a ſcrew-link in them, by which the buſhels can be all made to ſhut cloſe at the ſame time. Beneath each buſhel is a wooden hopper, L, into which the coals are emptied when the bottom of the buſhel is opened, and the ſacks are hung to this hopper to receive the coals; there are two ſmall hooks at the back of the hopper, to which the mouth of the ſack, M, is hooked; *h* is an iron bar, with a hook at each end, to faſten to the ſack; two ſmall cords are tied to this bar, which paſs over two pulleys, and are both faſtened to a ring that is hooked on a pin, driven into the hopper, in order to keep the ſack's mouth cloſe up to the hopper.

The operation of the machine is as follows: the coals are filled into the buſhels by three men, and are heaped up until they touch the plummet, *d*, ſuſpended by a chain from the ceiling; when the coal-meter, who ſits before the deſk, N, ſees, through the window, that they are properly filled, he takes the rope, I, with one hand, and with the other ſlips the ring, at the end of K, off the pin, as before deſcribed; the weight of the coals, reſting on the bottoms of the buſhels, then cauſes them to open, and the coals fall into the ſacks beneath; he holds down the rope, I, until the buſhels are all emptied, then lets it return, and hooks the ring on the pin. The bottoms of the buſhels are made to ſhut, by one of the ſpaces between the arms of each wheel, E, being filled with lead, which is equal to about half the weight of the coals; when the ſacks are filled, they are placed in a hand-barrow, and are wheeled into the waggon, the ſtage, R, being juſt the ſame height from the ground, as the floor of the waggon, which is backed up againſt it.

COAL-*Mines*. See COAL. By 10 G. II. c. 32, if any perſon ſhall wilfully and maliciouſly ſet on fire any mine, pit, or delph of coal, or cannel-coal, he ſhall be guilty of felony, without benefit of clergy. By 13 G. II. c. 21, if any perſon ſhall convey water to any coal-work, with deſign to deſtroy or damage the ſame, he ſhall pay to the party aggrieved treble damages with coſts, recoverable in any court of record at Weſtminſter. By 9 G. III. c. 29, any perſon demoliſhing engines, waggon-ways, bridges, &c. belonging to coal-mines, or cauſing the ſame to be done, ſhall be guilty of felony, and be tranſported for ſeven years: the proſecution on this act being within 18 months. By 39 and 40 G. III. c. 77, any perſon, deſtroying or damaging mines or roads leading to or from the ſame, ſhall be deemed guilty of a miſdemeanor, and may be impriſoned, on conviction, for any time not exceeding ſix months. Colliers and others, who wilfully and obſtinately work in a manner contrary to their agreements, or who do not fulfil their contracts, ſhall, on conviction, upon the oath of one witneſs, before one juſtice, forfeit not exceeding 40*s*., and upon non-payment, be committed to the common gaol without bail, for a time not exceeding ſix months, or till ſuch penalty and coſts ſhall be paid; and the contract ſhall become void. Perſons convicted of fraudently walling or ſtacking coal, &c. ſhall, on conviction, by confeſſion or oath of one witneſs, before one juſtice, be committed to the common gaol or houſe of correction, for any time not exceeding three months. If any perſon ſhall ſteal coals or implements, not exceeding the value of 5*s*., he ſhall, for the firſt offence, forfeit not exceeding 10*s*. over and above the coſts, or be committed to hard labour for one month; for the ſecond offence, not exceeding 20*s*., or be committed to the houſe of correction for three months; and for the third, or any future offence, not exceeding 40*s*., or be committed to hard labour for 6 months. All proſecutions under this act ſhall commence within nine months after the offence is committed.

COAL, *Old*, an inferior ſort of charcoal, made in Kent, and other places, from the roots of trees and underwood, for ſale to the founders, and others, in London, who uſe it for ſome common purpoſes, as a ſubſtitute for charcoal.

COAL *Orton*, or *Cole-Orton*, a rectory in the hundred of Eaſt-Goſcote, in Leiceſterſhire; it is ſituate very high, yet its coal-mines have attracted the rail-way extenſions of canals, in two different directions, *viz*. the *Leiceſter* and the *Aſhby-de-la-Zouch*. See CANAL.

COAL, *Patent*, is applied to a ſubſtance manufactured in Millbank Street, Weſtminſter, under a patent, granted to Mr. Chabannes, (ſee *Repertory of Arts*, XV. 367.); it conſiſts of the ſmaller parts, ſifted out of the ſea-coals, uſed for culinary purpoſes, before they are ſold, mixed up with a certain proportion of dirt and ſweepings of the ſtreets, which mixture is watered and tempered together, until fit for making into ſmall bricks, of which great numbers are ſet to dry in a large open-boarded ſhed. One or two of theſe coal-bricks, put into a coal-fire, are ſaid to continue the intenſity of its heat for a long time. See COAL-*balls*.

COAL-*Port*, the name given by the late Mr. William Reynolds, to a new town which he founded on the banks of the Severn river, at the entrance of the Shropſhire canal. See CANAL.

COAL, *Small*, is a ſort of charcoal, prepared from the ſpray and bruſh-wood, ſtripped off from the branches of coppice-wood, ſometimes bound in bavins for that purpoſe, and ſometimes prepared without binding.

The wood they diſpoſe on a level floor, and, ſetting a portion of it on fire, they throw on more and more, as faſt as it kindles; whence ariſes a ſudden blaze, till all be burnt that was near the place. As ſoon as all the wood is thrown on, they caſt water on the heap from a large diſh or ſcoop; and thus keep plying the heap of glowing coals, which ſtops the fury of the fire, while, with a rake, they ſpread it open, and turn it with ſhovels till no more fire appears. When cold, the coals are put up into ſacks for uſe. Small coal was formerly much more in uſe in London than it is at preſent. The ſiftings of charcoal are called *charm* by the London dealers.

COAL-*ſoot*. See SOOT.

COAL *ſpirits*. Coals diſtilled in a retort not only afford a phlegm and black oil, but a ſpirit, or gaſeous matter, which is

apt to force the lute and break the glasses, now known to be hydrogen gas: bladders may be filled with this inflammable air, which may be kept a considerable time. If the bladder be pierced with a pin, and squeezed near the flame of a candle, the gas will take fire, and afford an amusing spectacle. See Phil. Transf. N. 452. sect. 5. See DAMPS and GAS-*Lights*.

COAL-*tar*. See TAR.

Coalbrookdale

COALBROOK DALE, in *Geography*, a village of Shropshire, about 13 miles from Shrewsbury, which exhibits to the traveller the beneficial effects of manufacture and commerce, in its celebrated iron works, as well as a variety of romantic scenes. The river Severn winding between high wooded hills, opposite to the forge of Brofeley, is crossed by a bridge of one arch, 100 feet in length, and formed entirely of cast-iron, with strong stone abutments, which presents at once a striking effect in landscape, and a stupendous specimen of the powers of mechanism. This was the first iron bridge erected in England, and was cast in 1779, under the direction of Mr. Abraham Darby. Besides the communication of these works with the Severn river, they have a branch of the Shropshire canal extended to connect with their rail-ways. See CANAL.

Coating

COATING, in its general fenfe, denotes the covering of a body, or the fpreading of one fubftance over another; and this is practifed, with various views, in civil economy, in the arts, and in fome fcientific branches of knowledge. Thus, human beings are covered with various garments, both for defence and for ornament; houfes, veffels, and moft works of wood, are covered with paint, or pitch, or lead, or copper, or other matter, for the fame purpofes; the bafer metals are covered with the richer, filver is coated with gold, copper with gold or filver in ornamental works; iron or copper is coated with tin for culinary purpofes, in order to prevent the rufting of the former, and the noxious effects of the latter; and fo forth. See the practical methods of performing thefe operations under the articles PAINTING, PLASTERING, GILDING, SILVERING, TINNING, &c.

COATING, in *Chemiftry*, is ufed principally for the purpofe of defending certain veffels from the immediate action of fire; thus, glafs retorts and the infide of fome furnaces are coated with various compofitions. See LORICATION, and LUTING.

COATING, in *Electricity*, means the covering of electric bodies with conductors, or the latter with the former, or, laftly, electrics with other electrics. Electrics are coated with conductors, for the purpofe of communicating to, or removing from, their furfaces, the electric fluid in an eafy and expeditious manner; otherwife an electric body, on account of its non-conducting property, cannot be electrified deprived of the electric fluid, without touching almoft every point of its furface with an electrified or other body. This coating generally confifts of tin-foil, fheet-lead, gilt paper, gold leaf, filver leaf, or other metallic body, either in the form of a thin extended lamina, or in fmall grains, fuch as brafs filings, and leaden fhot. The coating may be faftened to the furface of the electric by means of pafte, glue, wax, or other adhefive matter. In lining Leyden phials, care fhould be had not to faften the coating (if it confifts of brafs filings or gold leaf) with varnifh; for this is apt to take fire on making the difcharge. But in fome cafes the metallic coating is merely laid upon the electric; for inftance, in certain experiments, a piece of tin-foil, or a brafs plate, is laid upon a pane of glafs, fo that after having charged the glafs, the coating may be eafily fhook off; and a Leyden phial is, fometimes, partly filled with leaden fhot, which performs the office of an inner coating, and may be eafily poured out of it. Alfo, when two extended parallel metallic furfaces are placed at the diftance of about an inch or two from each other, the intervening ftratum of air (being an electric) is faid to be coated, and may be charged and difcharged like a Leyden phial. When the electric is of a very fufible nature, fuch as fulphur, fhell-lac, fealing-wax, &c. a cafe of it may be coated by pouring it melted upon a metallic plate, or in a cup, which is required in certain experiments. See ELECTRICITY, ELECTROPHORUS, and LEYDEN *phial*.

In certain cafes conductors are coated with electrics, either partially or entirely, for the purpofe of preventing the abforption or diffipation of the electric fluid from their furfaces. This is done with varnifh, or more effectually with fealing-wax, the latter of which, when the fhape and fize of the conductor allows it, may be eafily performed by warming the conductor to a certain degree, which is indicated by actual trial, and then rubbing a ftick of fealing-wax over its furface.

Laftly, the coating of electrics with other electrics, is principally, if not exclufively, practifed with articles of glafs; for, fince moifture eafily adheres to the furface of glafs, the infulating quality of the latter is thereby greatly diminifhed and often annihilated; hence the glafs feet of infulating ftools, the glafs handles of directors, the pillars of fome electrical machines, &c. are generally covered with fome other electric fubftance of a refinous quality, which is not apt to attract moifture. The fubftances principally ufed for this purpofe are fealing-wax and varnifh. When the glafs article is fufficiently fmall, the beft way of covering it with fealing-wax is, to heat the former, and then to rub a ftick of fealing-wax over it, fo as to form an equal coat of the wax over the furface of the glafs; and this is, by far, the beft mode of obtaining the defired object; but when the piece of glafs is too large, then the fealing-wax muft be diffolved in fpirit of wine, and muft afterwards be fpread over the glafs with an hair pencil; having previoufly wiped the glafs perfectly clean and dry. In this cafe, however, care muft be had to ufe the beft rectified fpirit of wine, or alcohol; for if impure fpirits be ufed, the folution of fealing-wax, when fpread upon the glafs, will infulate very imperfectly, or even not at all. Of the diffolved fealing-wax you may lay two, three, or more, coats upon the glafs, always allowing one coat to become perfectly dry, before the next is put on.

With refpect to the ufe of varnifh, it muft be obferved, that very few of the common varnifhes will anfwer this purpofe in any tolerable degree. This is one, however, which, when properly made, and carefully applied, anfwers as well as the fealing-wax coating. This varnifh, which was long kept a fecret, is made in the following manner: Take half a pint of linfeed-oil, one ounce of faccharum faturni, and one ounce and a half of litharge. Set them in an iron veffel to boil over a fmall charcoal fire (*viz.* fuch as is barely fufficient for the purpofe), ftirring the materials frequently with an iron fpatula or an old knife. As foon as thefe ingredients are incorporated, add one ounce and a half of prepared amber, and let it continue to boil, ftirring the materials frequently, until you find upon trial, that a drop of the liquor, placed between two knife blades, ftretches like thick glue, or like turpentine. When this takes place, remove the veffel from the fire, fuffer it to cool a little, and then mix fpirit of turpentine with it, ftirring the whole together, which will thin it; but take care not to render it too thin; for by keeping, in a few days, it will of itfelf grow thinner. Laftly, keep it in bottles for ufe. *N. B.* The iron veffel muft be much larger than the quantity of ingredients might require, and it muft be furnifhed with a handle, becaufe the oil, &c. in boiling, is apt to fwell and will run over, if the veffel be not quickly removed from the fire. The amber is prepared, firft, by powdering it; fecondly, by melting, or rather charring it, in a fhovel over the fire; and, laftly, powdering it again in a mortar. This varnifh is ufed in the fame manner as the above-mentioned folution of fealing-wax; but you need not lay on more than one coat of it, or, at moft, two.

Cobalt

COBALT, *Kobolt*, Germ. in *Mineralogy*. Cobalt is a metal of a white colour, inclining to bluiſh, or ſteel-grey; when tarniſhed, acquiring a reddiſh tinge; its fracture is compact, fine-grained, and uneven. Its ſpecific gravity is 8.53. It is attracted by the magnet, and is itſelf capable of polarity. At a common temperature it is brittle, and eaſily reduced to powder, but when red hot may be ſlightly extended under the hammer. It requires for its fuſion nearly the ſame heat as caſt iron does. When in the ſtate of oxyd it tinges the ſaline vitreous fluxes of a deep blue. It is ſoluble in nitro-muriatic acid, and the ſolution forms a blue-green ſympathetic ink.

§ 1. *Ores of Cobalt.*

Cobalt occurs, 1ſt, mineralized by arſenic; 2d, as an oxyd; 3d, combined with arſenic acid; 4th, combined with ſulphuric acid.

Sp. I. *Arſenical Cobalt.*

Cobalt is never found pure in the metallic ſtate, but is

always alloyed with arsenic, and often besides contains iron and sulphur, and sometimes nickel, bismuth, and silver.

Of the sub-species only the crystallized (3d sub-species) has been analyzed, and both by Klaproth and Tassaert. The following are the results. Klaproth obtained

Cobalt	-	44.
Arsenic	-	55.5
Sulphur	-	0.5
		100.0

Tassaert obtained

Cobalt	-	36.66
Arsenic	-	49.
Iron	-	5.66
Sulphur	-	6.5
		97.82
Loss	-	2.18
		100.

Similar differences are observed between the analyses of this variety by other chemists, so that it may be considered as allowing considerable range both in the proportion and nature of its constituent parts, without materially affecting its crystallization. It appears, however, from Hauy, that when the crystals display a lamellar fracture, they contain a notable proportion of sulphur and iron. We shall follow Brochant's arrangement of the sub-species.

1. Sub-species. White cobalt. *Weisser Speiskobolt. Cobalt blanc*, (species 2 of Kirwan and Hauy).

The colour of this mineral, when recently broken, is tin-white, but its surface is generally yellowish, bluish, greyish, or iridescent, like steel that has been heated. It occurs in mass, disseminated, kidney-shaped, and rarely in minute quadrangular tables, or imperfect cubes and octohedrons. Their external lustre is slight, but internally is brilliant and metallic. Its fracture is fine-grained and uneven: when broken, it flies into sharp-edged irregular fragments: when in mass, it contains fine-grained granular distinct concretions. It requires a polish by friction, is brittle and hard: when exposed to the blow-pipe, white cobalt melts with great ease, giving out a white vapour, and a strong arsenical odour, and a white brittle bead of metal remains, which gives a blue colour to glass of borax, when melted with it.

It is found in Norway, at Tunaberg in Sweden, Annaberg in Saxony, and also, rarely, in Swabia and Stiria. In Saxony and Norway, it is contained in beds of micaceous schistus, accompanied by the red earthy cobalt, quartz, hornblende, and pyrites.

2. Sub-species. Dull-grey cobalt. *Grauer Speiskobolt. Cobalt gris*, (sp. 1. of Kirwan and Hauy.)

The colour of this mineral is a clear steel-grey, but by exposure to the air it acquires an iridescent tarnish. It occurs in mass or disseminated, sometimes in kidney-shaped or clustered masses, and very rarely in specular laminæ. Its external lustre is very feeble, but internally it exhibits a bright metallic lustre. Its fracture is compact, generally even, but sometimes passing into flat-conchoidal; its grain is remarkably fine and close. Its fragments are sharp-edged, indeterminate. It is not so hard as the preceding, and is less brittle. Its specific gravity varies from 4.3 to 5.3, or even 5.5. It gives a bluish-grey metallic streak.

When exposed by itself to the blow-pipe, it gives out an arsenical vapour and smell; but seldom fuses: when treated in the same way with borax it gives the flux a blue colour, and is reduced to a metallic globule.

A specimen from Cornwall was analysed by Klaproth, who procured from it about 20 per cent. of cobalt, 24 of iron, and 33 of arsenic, the remainder consisting partly of bismuth and sulphur, together with earthy matter. Some varieties have also been found to contain nickel and silver. It is found in Saxony, Bohemia, Swabia, and Hungary; also in Stiria, France, Norway, and Cornwall.

3. Sub-species. Bright white cobalt. *Glanz Kobolt. Cobalt eclatante.*

The colour of this mineral is tin-white, but tarnishes to greyish, whitish, or iridescent. It is found in mass, disseminated or investing, or of particular shapes, as clustered, kidney-shaped, globular, or crystallized in cubes or octohedrons. The crystals are middling-sized or small, their surface is commonly smooth and brilliant, and marked with striæ on the sides of the primitive cube. The fracture of the crystals is lamellar, that of the other varieties is fine-grained, uneven, or radiated. When in mass it presents granular, or lamellar, or testaceous distinct, concretions. Its hardness is somewhat inferior to the preceding sub-species: when pulverized, it is of a steel-grey colour. Sp. gr. 6.2 It is brittle, and easily frangible.

Before the blow-pipe, it burns with a faint white flame, disengaging arsenical vapours; it then becomes black, is attractable by the magnet, and is, with the utmost difficulty, reduced to a metallic globule. It often contains as much as 50 per cent. of reguline cobalt.

This is the commonest of all the ores of cobalt: it occurs for the most part in primitive mountains, together with the other species of cobalt ore, with vitreous, red, and native silver, with arsenical and cupreous pyrites, &c. It is met with in various parts of Germany; also in Sweden, Norway, Stiria, and Cornwall.

Sp. II. *Earthy Cobalt.*

Of this there are the four following varieties:

Var. 1. Friable black cobalt. *Schwarzer Kobolt muhn. Cobalt terreux noir friable.*

The colour of this is black, bluish, brownish, or greyish black. It is without lustre, has a loose earthy consistence, is friable and meagre, stains the fingers in a slight degree, and gives a brightish streak. It is soluble in muriatic acid; tinges borax blue, and very rarely shews any indications of sulphur or arsenic, when treated by the blow-pipe.

Var. 2. Indurated black cobalt. *Verhærteter schwarzer kobolt. Cobalt terreux noir endurci.*

In colour it resembles the preceding, except that it is sometimes of a dark greenish black. It occurs massive, disseminating, investing, kidney-shaped, clustered, or in veins. It is dull, but takes a polish by friction. Its fracture is earthy and compact, passing into flat-conchoidal. It possesses a moderate degree of hardness. Sp. gr. from 2. to 4. With nitric acid it gives a red solution, and a bluish-green one, with muriatic acid. It has not been accurately analysed, but consists of oxyd of cobalt, with a small variable proportion of arsenic and sulphur mixed with vitreous silver ore, oxyd of iron, and clay.

This, and the preceding variety, are always found together; but the indurated is by much the most rare. It is found in Saxony, Thuringia, Swabia, and the Tyrol.

Var. 3. Yellow cobalt. *Gelber erdkobolt. Cobalt terreux jaune.*

Its colour is that of faded straw, passing into yellowish white, and often streaked with brick-red. It is found in mass, disseminated or investing. It is without lustre, has a

fine-grained earthy fracture, gives an unctuous streak, and is soft and friable.

It is infusible *per se*, gives a feeble, arsenical odour, and communicates a deep blue tinge to borax: but when mixed with iron, as it often is, the colour is greenish.

This is one of the rarest of the ores of cobalt. It has hitherto been found only in Thuringia, Wirtemberg, and Dauphiné.

Var. 4. Brown cobalt. *Brauner erdkobolt. Cobalt terreux brun.*

Its colour is a clear liver-brown, passing into grey, yellow, and black. It occurs in mass or disseminated; it is dull, but acquires a greasy lustre by friction. Its fracture is fine-grained, earthy. It is easily broken, being almost friable. It has been analysed, but appears to be the connecting link between the second and third varieties. When thrown on burning coals, it generally gives out an arsenical odour.

Sp. III. *Red Cobalt.*

Of this there are two varieties.

Var. 1. Crystallized. *Koboltblute. Fleurs de Cobalt.*

The usual colour of this mineral is peach-blossom-red, passing into cochineal and greyish-red; by exposure to the air it becomes paler, and almost white. It is found very rarely in mass, or disseminated, and still seldomer clustered, or kidney-shaped; its most usual state is that of a thin crystalline covering, or minute druses of crystals. The forms which it generally affects are rectangular tables, or tetrahedral acicular prisms, or hexahedral prisms terminated by dihedral summits: these figures, however, are not often determinable, on account of the minuteness of the crystals, and their tendency to form radiates and globular groupes. The surface of the crystals is smooth and brilliant, and their fracture lamellar. The fracture of the other kinds is radiated, passing into fibrous. It is translucent, and often, when crystallized, semi-transparent.

Before the blow-pipe it gives a faint arsenical odour, and becomes of a dark-grey colour; it is almost infusible by itself, and gives a beautiful blue tinge to borax.

Var. 2. Earthy. *Koboltbeschlag. Cobalt terreux rouge pulverulent.*

The colour of this is the same as that of the preceding variety. It occurs in a pulverulent or indurated state, disseminated through, or investing other minerals, and occasionally in mass. It is dull, opake, and has an uneven earthy fracture. In other respects it agrees with the preceding.

Sp. IV. *Native sulphat of cobalt. Naturticher koboltvitriol. Sulfate de cobalt natif.*

At Herrengrund, near Neusohl in Hungary, is found a saline substance, in the form of translucent stalactites, of a pale rose-red colour. It was at first supposed to be sulphat of manganese, but from an analysis of Klaproth, it appears to be a pure sulphat of cobalt.

§ 2. *Reduction of the Ores and Analysis.*

Cobalt is never employed in manufacture in the reguline state; the sole use of this very valuable metal being to give various shades of blue colour to glass and enamel, and when thus employed, it is in the state of oxyd. In this state it forms either *zaffre*, or *smalt*, when prepared in the method, which will be described in the next section.

Many of the cobalt ores are complicated, and difficult to be analyzed completely, nor is it easy to obtain the cobalt alone from them in considerable purity. The metals naturally varied with cobalt are the following: 1st, arsenic, generally in very large quantity, part of which is in the reguline state, and, as appears, another part is in the state of arsenic acid, which, uniting with the oxyd of cobalt, forms an arseniat of cobalt, that has often been mistaken for the pure oxyd. The entire separation of the two is extremely difficult. 2d. Nickel exists with many cobaltic ores; and being soluble in the same menstrua, it is not easily separated. 3d. Iron, in variable quantity, is found with most of the ores of cobalt, and is hurtful, as it impairs and degrades the fine blue for which alone cobalt is valued. 4th. Manganese, which is a still worse admixture. 5th. Copper, in small quantity, is sometimes found, which, however, does not much injure the cobalt.

An imperfect analysis of the common cobalt ores, and which merely has for its object the extraction of the cobalt, is made in the following way: Mix the ore, in fine powder, with charcoal or saw-dust, and roast it in a low red heat, till the arsenic is driven off, and no arsenical fumes are any longer perceived. Calcine the residue some time longer with a strong red heat, and in an open fire, and then mix it with about four parts of a saline, reducing flux, (such as that composed of equal parts of tartar and carbonat of potash) and heat it in a roomy covered crucible, at first moderately, till the first swelling of the materials has subsided, and then for a quarter of an hour in a heat fully sufficient to melt iron. When cold, a button of reguline cobalt is found beneath a mass of scoriæ of an intense blue-black colour. From 100 grains of the Tunaberg ore, Klaproth obtained in this way 44 grains of regulus of cobalt, which, however, must have been still very impure, retaining iron and a portion of the arsenic. It may be further purified by alternate deflagration with nitre, and reduction with a saline carbonaceous flux, repeated two or three times, in the way that Lampadius and Tromsdorf have employed with smalt, as will be presently mentioned.

The reducing flux for cobalt ore, employed by Beaumé, is the following: Mix 1 oz. of the roasted ore with 3 oz. of black flux, and $\frac{1}{2}$ oz. of carbonat of potash, cover it when in the crucible with about 1 oz. of salt, and heat the whole, at first slowly, and afterwards very briskly for a quarter of an hour.

But, for the purposes of mere analysis, where all the constituent parts of the ore are required to be known with as much precision as possible, these methods are much too inaccurate to be depended on, and recourse must be had to the more tedious and difficult analysis in the humid way. The process given by Tassaert (An. de Chim. tom. 28.) is highly valuable and instructive.

The method given by Lampadius, of purifying cobalt by fusion is the following: Project in a red-hot crucible a mixture of 4 oz. of zaffre, 2 oz. of nitre, and $\frac{1}{2}$ oz. of charcoal. A strong arsenical smell is perceived in the process, and a blackish-grey mass is left, which is to be again mixed with charcoal and nitre and deflagrated as before: then throw in the crucible 2 oz. of black flux, and heat it intensely for an hour. This gives a tolerably pure regulus of cobalt, weighing 6 drams. Powder it, and mix it with 1 dram of nitre, and as much manganese; put it into a luted double crucible, and heat it for an hour in a forge-furnace. The metal, by this operation, loses all its iron and is nearly pure.

Tromsdorf's process is the following: The zaffre, or smalt, is to be twice detonated with nitre, then washed in hot water, which carries off the arsenic now united with the potash of the nitre, and the residue is to be digested in dilute nitric acid, which will only touch the cobalt and leave the iron. The nitrous solution may then be decomposed by an

alkali, and the purified oxyd of cobalt, thence resulting, may be afterwards reduced if required.

§ 3. *Preparation of Zaffre and Smalt, or Azure.*

All the zaffre and ſmalt of commerce are prepared in ſome parts of Germany, and particularly at Schneeburg in Miſnia, which affords a very lucrative trade to Saxony. The following is the method of preparation as given by Kunckel. (See *Neri's Art de la Verrerie.*) The cobalt ore, broken in ſmall pieces, is ſpread on the hearth of a furnace, like a baker's oven, ſo conſtructed that the flame of the wood is reverberated on all ſides over the ſurface; which ſoon heats it red-hot. A very denſe arſenical vapour then ariſes, which is conveyed from the furnace into a horizontal wooden ſquare trough, or chimney, ſometimes of the enormous length of a hundred fathoms, where moſt of the arſenic is condenſed and collected for ſale. The cobalt ore is calcined for ſome hours, till it ſcarcely emits any more vapours, after which it is taken out, ground to fine powder, replaced in the oven, and calcined a ſecond time, and then again ground and paſſed through a very fine ſieve. This powder is then mixed with about twice its weight of powdered flint or quartz, wetted to the conſiſtence of ſtiff mortar, and rammed into ſmall barrels, where the maſs ſoon acquires a ſtony hardneſs, and is then the *zaffre* of commerce. The reaſon of uſing the flints appears to be partly to dilute the cobalt ore, and partly for ſome purpoſe of concealment; the exportation of the ſimple calcined ore being forbidden under heavy penalties.

Smalt, ſometimes alſo called *azure blue,* when finely powdered, (which muſt not be confounded with the true *azure,* or *lapis lazuli*) is an intenſely deep blue glaſs, made of the calcined cobalt ore and the common vitrifiable fluxes, which is uſed as a colouring matter for a variety of purpoſes. The intenſity of colour of courſe depends on the proportion of roaſted cobalt ore which it contains, regard being had to its quality, and the proportion of oxyd of cobalt which it is eſtimated to contain. On an average about equal parts of the roaſted ore of potaſh, and of ground flints are uſed. This mixture is firſt *fritted,* and then melted in pots ſimilar to thoſe of glaſs-houſes, and about ten or twelve hours of fuſion are required. When the glaſs is thoroughly fuſed, it is laded out and dropped into cold water to crack it in every direction, and then ground in a mill made of a very hard ſtone. At the bottom of the glaſs-pots a quantity of regulus of biſmuth is always found, lying under a mixed alloy of arſenic, iron, and copper.

The grinding of the blue glaſs is a work of much difficulty, and different degrees of fineneſs of the powder are obtained by ſubſequent waſhing and ſifting.

Smalt is a valuable colour, on account of the fine body which it poſſeſſes; and being indeſtructible in any heat, it is uſeful for all enamel colours, but it will not mix with oil colours, and therefore can only be partially uſed. Starch is ſlightly coloured with it to give a ſmall degree of blueneſs, which corrects the yellow hue which linen and cotton acquires by being worn.

Zaffre is alſo prepared in Bohemia, Wirtemberg, Sileſia, and Lorraine, but the Saxon is preferred.

The oxyd of cobalt contained in the zaffre is ſtill intimately mixed with a ſmall portion of arſenic, partly as arſenic acid, and partly as oxyd of arſenic. If zaffre is digeſted in liquid cauſtic ammonia, a red ſolution is formed, which, on evaporation, depoſits a yellow powder, which is a mixture of the oxyds of cobalt and arſenic. If zaffre is boiled in water, a ſolution is alſo obtained, which is ſenſibly acid, and was thought by Brugnatelli to indicate the exiſtence of a cobaltic acid, but Darracq has ſhewn it to be an arſeniat of cobalt.

§ 4. *Chemical Properties of Cobalt*

Cobalt, when perfectly pure, has a ſteel-grey colour, not very reſplendent, and when ſlowly cooled, has ſomewhat of a reticulated texture. It melts at about the fuſing point of caſt iron.

Cobalt, when heated ſtrongly in contact with air, is converted into a black oxyd, with an increaſe of about 18 parts on 100; hence 100 parts of the oxyd contain 84.75 of metal, and 15.25 of oxygen. When it retains any arſenic, the colour is reddiſh.

This metal burns in oxymuriatic acid gas, with a bright white flame.

The ſulphuric acid diſſolves cobalt with difficulty, but its oxyds more readily. If zaffre, or which is better, the wet precipitate from nitrat of cobalt by carbonat of potaſh, is digeſted with ſulphuric acid, and the mixture evaporated nearly to dryneſs, the reſidue digeſted with hot water, gives a ſolution of ſulphat of cobalt, which, by ſlow evaporation, affords the ſalt in cryſtals, that are of a fine red when the metal is pure, but greeniſh when it contains nickel. This ſalt is ſoluble in 15 parts of boiling, and 24 parts of cold water.

Nitric acid diſſolves cobalt or its oxyd copiouſly and with great eaſe by digeſtion in a moderate heat. The ſolution is red, or claret-coloured, or yellow, if it holds iron. It ſcarcely can be brought to cryſtallize, but by evaporation to dryneſs and calcination, it leaves a dark red or violet oxyd.

Muriatic acid acts with great difficulty on cobalt, and can ſcarcely be made to diſſolve it, unleſs by repeated evaporations to dryneſs and affuſion of freſh acid. But it diſſolves the oxyds of this metal with much more eaſe when aſſiſted by heat. The ſolution is of a roſe-red, but when evaporated to dryneſs and warmed, it acquires a beautiful blue-green, which more approaches to blue in proportion as the ſolution is free from iron. This ſingular property of the muriat of cobalt was firſt diſcovered by Hellot, and uſed in making a beautiful *ſympathetic ink,* the properties of which have engaged much of the attention of chemiſts. If the ſolution be conſiderably diluted, characters traced by it on paper are ſcarcely viſible when cold, but when held near the fire, they very ſpeedily aſſume a beautiful blue green, which colour again totally diſappears when cold, and may be made to re-appear at pleaſure by the ſame means. The paper, however, ſhould not be heated more or longer than is neceſſary to produce the full effect. It is found, that not only the pure muriat of cobalt, but any ſolution of this metal into which muriatic acid, or a muriatic ſalt, enters, will have the ſame effect. Hence the commoneſt method of making this ſympathetic ink, and that employed by the inventor, is, to digeſt zaffre in a moderate heat, with a mixture of about three parts of nitric and one of muriatic acid, diluted with as much water, till a high claret-coloured ſolution is formed, which ſhould then be diluted with as much water as poſſible, to prevent the paper from being corroded by the acid. But a much more concentrated ſolution may be made, which ſhall not injure the paper, in the following way: Boil ſome moderately dilute nitric acid or zaffre, till much of the cobalt is diſſolved out of it, then add to it any alkali as long as any precipitate takes place; pour off the clear liquor after ſtanding ſome time, waſh the ſediment with hot water, and throw it on a filter. Take the ſediment which is left on the filter, and put it, while ſtill wet, into a glaſs flaſk, and boil

it with diftilled vinegar, which will readily diffolve it, and make a rofe-coloured folution, which may then be made into a fine fympathetic ink, by diffolving in it fome common falt or fal-ammoniac.

It has been mentioned that the colour of the common cobaltic fympathetic ink is green, and when made fimply by diffolving the foluble part of zaffre in nitro-muriatic acid, it is generally a pale grafs green, but in proportion as the cobalt becomes purer, the colour approaches to a bright blue green. This is probably owing to the feparation of iron which the common zaffre contains in abundance, and which may be effected more or lefs perfectly in various methods. The fimpleft (though not the moft economical) is to add to the folution very gradually carbonat of potafh as long as the precipitated oxyd is rofe-coloured, and to ceafe when it begins to have a yellow ochery hue; for the former confifts chiefly of the cobalt, and the latter chiefly of the iron. Then by collecting, wafhing, filtering, and re-diffolving the rofe-coloured precipitate in the nitric or acetous acid, a much purer folution is obtained, which contains very little iron, and gives a blue-green fympathetic ink, when any muriatic falt is added. Another way of feparating moft of the oxyd of iron is to evaporate the nitrous folution nearly to drynefs, and to expofe it for fome time in a fhallow veffel to the air, by which much of the iron will be rendered infoluble, and fubfide as a red ochre, whilft the cobalt will remain in folution. Or elfe the acetited folution of both metals may be alternately evaporated to drynefs, and the foluble part re-diffolved by frefh acetous acid, for two or three times fucceffively, by which the iron will gradually feparate, and the cobalt alone be left.

But to obtain perfectly pure cobalt, feparate from arfenic, bifmuth, iron, and other impurities, is more difficult, for in the above-mentioned proceffes the arfenic acid and oxyd contained in the cobalt ore muft accompany the cobalt and be retained in all the folutions. We fhould therefore recommend the following method: Digeft a quantity of zaffre with nitric acid diluted with about three times its weight of water, and boil them for fome time. After ftanding for a while pour off the clear folution and evaporate it nearly to drynefs. Then dilute it pretty largely with water, which will caufe the bifmuth, if any, to fubfide. Then neutralize any excefs of acid in the filtered folution by any alkali, avoiding to precipitate any of the metal which it contains, and add, cautioufly by drops, fome of a folution of nitrated lead (made by diffolving the cryftals of this falt in water) as long as any precipitate falls down. This latter is arfeniat of lead, and by this means all the arfenic acid of the zaffre will be removed. Then entirely decompofe the clear folution by cauftic potafh, collect and wafh the precipitated oxyd put into a phial, and add to it fome cauftic ammonia, which will diffolve only the oxyd of cobalt. From this ammoniacal folution all the oxyd may be again feparated either by evaporation to drynefs, or by boiling with cauftic potafh, and a very pure black oxyd of cobalt is left, which may be reduced to the metallic ftate by being heated intenfely in a covered crucible lined with charcoal; or it may be diffolved in the feveral acids. This method, however, is expenfive, on account of the quantity of ammonia employed, but it is difficult to exclude the iron totally by any other method.

A triple falt of cobalt, nitric acid, and ammonia, is made by adding ammonia to nitrat of cobalt, which may be cryftallized.

The fixed alkalies have little or no action on cobalt or its oxyds in the moift way, but ammonia diffolves the oxyds largely, as already mentioned.

Tincture of galls give a yellowifh white, and pruffic acid a green precipitate to the folutions of cobalt when free from iron.

Sulphur unites with great difficulty to cobalt by fufion, but the hydrofulphurets and liver of fulphur readily diffolve this metal. Hydrofulphuret of potafh added to the folutions of cobalt gives a very black precipitate, which an excefs of the hydrofulphuret again diffolves. Cobalt ore fufed with liver of fulphur is diffolved thereby, and a brilliant metallic looking mafs is produced, which deliquefces totally by expofure to air, and falls into a dark liquid.

None of the poffible alloys of cobalt deferve any particular notice, for this metal has only a fingle ufe in the arts, namely, that of giving a blue colour to vitrefcent compounds when its oxyd is melted with them, and this colouring power is fo intenfe, that a fingle grain of the pure oxyd (or zaffre in proportion) will give a very deep blue to half an ounce of glafs. When the glafs contains much more than this proportion, the body of colour is fo intenfe as to render it nearly opake, and hence, too, it is of ufe in forming the black glaffes and enamels.

The affinities of cobalt are ftated to be in the following order, *viz.* the gallic, oxalic, muriatic, fulphuric, tartareous, nitric, phofphoric, acetic, arfenic, and carbonic acids, and ammonia. We may add, however, that the difficulty of obtaining pure cobalt, and the variety of metals with which it is ufually alloyed, render this order of affinity fomewhat doubtful.

Cobalt is alfo ufed by fome to exprefs that fuffocative vapour or damp in mines, which often proves fatal to the miners. It is common among the Germans, to fay on this occafion, that the cobalt rofe and choaked them. See Damps.

Coke

COKE, or *Coak*, denotes pit-coal or ſea-coal charred. For the exciting of intenſe heat, as for the ſmelting of iron-ore, and for operations where ſmoak would be detrimental, as the drying of malt, foſſil coals are previouſly charred, or reduced to coaks, that is, they are made to undergo an operation almoſt ſimilar to that by which charcoal is made. By this proceſs coals are deprived of their volatile parts, nothing remaining except the carbon and earthy impurities. The great quantities of coal duſt, or ſmall coal, collected at the numerous pits in the neighbourhood of Newcaſtle, would ſoon become a great incumbrance, were it not that an admirable method has been diſcovered, not only to prevent the inconvenience, but to turn it, with a little modification, into an article of commerce and advantage, by preparations as ſimple as they are ingenious. Coal, in this pulverized ſtate, is not proper for chamber fires, becauſe it falls through the bars of the grates, or extinguiſhes the fire by falling upon the ignited

cinders, in such a mass, that no air can get between to assist the combustion. This small coal is, therefore, proper in this state only for some purposes in glass-houses, lime or brick kilns, forges, &c. The consumption for these purposes is indeed very considerable, but is not nearly equal to the quantity produced by the pits, notwithstanding the great care that is taken to keep the coal in large pieces; besides, some kinds are liable to crumble into small-coal upon receiving the least shock: means have, therefore, been sought to render this coal proper for other purposes. That property, which belongs to the best coal, of agglutinating and forming a single mass, when in a state of combustion, naturally suggested the idea of endeavouring to consolidate considerable quantities of this coal dust, or small coal, by means of a great fire. To effect this it is put into a kiln, in a great degree similar to a lime-kiln, which is previously well heated with large pieces of coal. The small-coal then runs together, and forms a mass, without losing any large portion of its valuable qualities. When the ignited mass is completely red, large pieces of it are pulled out with iron rakes (such as are used in the copperas works), and laid separately on the ground, where they are very soon extinguished; these pieces are firm, though porous, and are excellently adapted for smelting iron, and other ores, in high furnaces. This simple and ingenious contrivance has given birth to several new branches of industry and commerce. The coal, thus prepared, is used in a great number of manufactories, where a draft or blast is used, as a substitute for charcoal, to which it is in most instances superior, as it produces a stronger, more equal, and longer continued heat. Such is the method of coak-making at Newcastle, and other places. That pursued in the great iron-works at Carron, near Falkirk, in Scotland, being so completely different, our readers will excuse our giving an account of this also. The business is conducted there in the open air, and in the most simple manner; a quantity of large coal is placed on the ground in a round heap, of from 12 to 15 feet in diameter, and about two feet in height; as many as possible of the large pieces are placed on their ends, to form passages for the air; above them are thrown the smaller pieces and coal dust, and in the midst of this circular heap, is left a vacancy of a foot wide, where a few faggots are deposited to kindle it. Four or five apertures of this kind are formed round the ring, particularly on the side exposed to the wind; there is, however, seldom occasion to light it with wood, for other masses being generally on fire, the workmen most frequently use a few shovels of coal already burning, which acts more rapidly than wood, and soon kindles the surrounding pile; as the fire spreads the mass increases in bulk, puffs up, becomes spongy and light, cakes into one body, and at length loses its volatile parts, and emits no more smoke. It then acquires an uniform red colour, inclining a little to white, in which state it begins to break into gaps and chinks, and to assume the appearance of the under part of a mushroom; at this moment the heap must be quickly covered with ashes, of which there is always a sufficient provision around the numerous fires, where the coak is prepared. This method of throwing a large quantity of ashes on the fire, to deprive it of the approach of air, is similar to that used in making charcoal, which is covered over with earth; the result is also pretty much the same, the pit-coal thus prepared being light and porous, and producing the same effect in high furnaces as charcoal. This is a quality of extreme value; since, by means of charred pit-coal, founderies may easily be established, in places where the want of wood for charcoal, would otherwise render it necessary to abandon even the richest mines of iron.

The simple method above described being found to consume much of the best qualities of the coke, owing to the too free access of air during the process; many years ago a method was introduced, of distilling, or charring coals, in close vessels, by the heat of another fire externally applied, and by which also the liquid bituminous matter, or coal-tar, was separated and condensed; the value of which, as a substitute for paint in rough works, contributed to render this a profitable mode of preparing strong cokes; for the smelting of metals, and other purposes in the arts, where, with greater plenty of wood, charcoal formerly was used; and which coke, from its superior inflammability, could be used in common grates and stoves, where the draft or influx of air is insufficient to burn the common coke. On the 13th of November, 1800, Mr. David Mushet of Glasgow took out a patent for various improvements in metallurgy, and, among others, for an improved coking furnace, built of fire-brick, or iron-plates, and made to exclude the external air from the coals to be coked while they are heated to incandescence, by a fire underneath with flues enveloping the coking vessel. In his specification (see Repertory of Arts, xiv. 182.), different constructions of these furnaces are described, some to condense the tar and soot, or lamp-black, and some for letting these escape, if their condensation should not be found advantageous. On the 18th May, 1804, Mr. Frederick Albert Winsor took out a patent for combining the saving and purifying of the inflammable gas (for producing light and heat), the ammonia, tar, and other products of pit-coal, with the manufacture of a superior kind of coke (see Repertory, 2d Series, v. 172.). And, lately, the same gentleman has taken out a second patent, for further improvements in these processes, but this specification not being yet filed (June 1807), we are unable here to describe minutely, and give drawings of the oven, or carbonizing furnace, as we wished to do, which he uses for preparing his patent coke, of a superior quality, as the residuum of the gas, ammonial liquor, and oil-tar, separated in his processes (see GAS-*lights*, and TAR-*coal*), in which 300 yards in length of the wall of Carlton-House gardens, next to the Mall in St. James's Park, were, on his majesty's birth-day evening last, lighted up with gas-lamps, and burners, of various constructions, and with transparencies, and other devices, illuminated by brilliant gas-lights. This patent coke, from the experiments which we have seen, seems perfectly applicable to burning in our rooms and apartments; making a lively and pleasant fire, with a very small degree of draught up the chimney, and producing no smoke. Two pecks of coals, weighing 36 lb. coked in one of Mr. Winsor's small carbonizing furnaces, produced $24\frac{1}{8}$ lb. of coke (or 67 per cent.), which, when broke into moderate sized pieces, measured three pecks. Dr. Watson obtained 58, Mr. Jars 63, and M. Hielm 73 per cent. of the weight of coals, in similar experiments.

In the smelting of ores in Silesia, it was found (1. Bergm. Journ. 1790. p. 320.) that 92 lb., or one measure of cokes, were equivalent to 180 lb., or three measures of charcoal; and, in another place (ibid. 1792. p. 60.), one measure of cokes is said to equal the effects of five measures of charcoal, or three of pit-coal.

From the experiments of M. Lavoisier, in the Stockholm Memoirs, 1781, p. 187, it appears, that the heats produced, as measured by the evaporation of equal quantities of water, under equal surfaces, and the times of consumption, to produce the same effect by four different kinds of fuel, were as follow, *viz*

Combustibles.	Weight.	Measure.	Duration.
Pit-coal,	600 lbs.	10 cubic feet.	20 hours.
Cokes,	403	17	$12\frac{1}{2}$
Charcoal,	600	40	5
Oak wood.	1089	33	4.4

Whence it appears, that if coal produces a certain quantity of heat in a given time, coke, in a much ſmaller quantity, will produce the ſame effect in little more than half the time; an equal weight of charcoal in one-fourth of that time; and oak wood, of nearly double the weight of coal, in about one-fifth of that time.

The coke-ovens, mentioned in a former part of this article, began about 30 or 40 years ago, to be applied to other purpoſes beſides the making of coke. About the year 1780, we remember to have ſeen a coke-oven, opening with a door almoſt like a large baker's oven, applied to heating the boilers of the ſteam-engines of the Chelſea or Pimlico water-works, but which has long ſince been diſuſed. On the 23d June 1789, the right honourable Henry Seymour Conway took out a patent (ſee Repertory of Arts, iii. 75.) for improved methods of conveying and adapting the heat of coke ovens to the working of ſteam-engines, baking of bread, calcining and fuſing of metals and ores, &c. We are told in this ſpecification, that three biſcuit-ovens were erected and worked from the fire of one coke-oven thus conſtructed, the heat from it being regulated by openings and regiſters, with perfect ſucceſs. See OVEN. Others of theſe coke-ovens were adapted for heating boilers, and for working ſtills.

The earl of Dundonald's method of making cokes, or cinders, after he had extracted the coal-tar from coals, for which he obtained a patent, 30th April, 1781, and the time of which was afterwards extended by act of parliament to the 1ſt of June 1806, required the admitting of the external air into his furnace, in ſufficient quantities to carry on the combuſtion of the coals operated upon (ſee Repertory of Arts, i. 145.), by which the neceſſity of a ſecond, or external fire, for heating the furnace was avoided; but the cokes, produced by this means, are inferior in quality to thoſe produced in cloſe veſſels, as in the proceſſes of Muſhet, Winſor, &c. above mentioned.

Colliery

COLLIERY. Under the article COAL we have recently given the hiftory of its mines and trade in Britain, its laws, the claffification and defcription of different forts of coal, the practice of coal-mining, and fome of the principles to be obferved in fearching for coals; this laft part admitting of farther and more general elucidation, we fhall refume the fubject in this place, and treat of the different opinions which naturalifts have held, refpecting the origin and formation of coals.

Mr. Richard Kirwan, a moft indefatigable collector of facts relating to geology, when fpeaking of carboniferous foils or coal meafures (Geological Effay, p. 290, &c.), ftates thefe to be either chiefly argillaceous or arenilitic, or both together, or of the trap kind, or calcareous; the circumftances of thefe, and of the coal found among them moft worthy of notice, he ftates to be the following; *viz.*

1°. They commonly form diftinct ftrata, or beds, one over the other to a great depth. The ftrata of coal are ufually called *feams* (beds); it is very feldom found in irregular heaps (pipe-veins, bellies, nefts), or veins (loads, fiffures, rake-veins, &c.).

2°. Thefe feams are fcarcely ever found *fingle*, but thofe whofe thicknefs does not exceed 14 or 15 inches, are rarely

worked. At Whitehaven five were lately worked, at Newcastle three, at Liege 20. The highest seams, and next the surface, are generally the worst (see §. 7°), but the deepest are not always the best.

3°. The thickness of different beds of coal is variable, from half an inch or less to 5 or 6 feet; but not unfrequently it amounts to 25 or 30 feet, and in some rare instances to 80 feet or more. No such seam as this last has occurred in Great Britain.

4°. Seams of coal generally occupy a considerable extent both in length and breadth, and whatever the thickness of each may be, it is commonly constant for a considerable space, as a mile or two miles; instances of a contrary kind seldom occur, unless the seam be disturbed by some obstruction (see § 16°), or at the extremities of a coal-soil, (coal-measures), or in an extent exceeding two miles.

5°. In the same stratum (seam) if exceeding 3 or 4 feet in thickness, the coal is seldom exactly of the same quality.

6°. Different seams of coal are separated from each other, by at least one, but generally by several strata of earth or stone (See article COAL); these, in a considerable extent, preserve also an uniform thickness.

7°. The uppermost seam of coal is commonly soft and dusty; it is vulgarly called *smut*.

8°. Seams of coal, and also their concomitant strata, are generally parallel to each other, unless an uncommonly thick stratum of earth, 150 or 200 feet thick, intervenes. Their number and order are also similar, to a considerable extent, yet variable in the same district and soil.

9°. In many of the concomitant strata, particularly of shale, bituminous shale, indurated clay, and sand-stone, particles of coal are found interspersed.

10°. The strata that immediately cover coal, and thence called its *roof* (crop), are shale, bituminous shale, or sand-stone; rarely any other. But they are also often found at a great distance above it.

11°. The strata on which coal reposes, and thence called its *floor*, *sole*, or *pavement*, are also sand-stone, shale, indurated clay, or semi-protolite (a reddish sand-stone or breccia). This last would, says Mr. Kirwan, in most cases, be found in its floor, if the mines were sunk deep enough to reach it. Granite has also been found in its floor in a few instances. In trap soils, trap or basalt is said to form sometimes the roof, and sometimes the sole of a seam of coal, but, in strictness, it is believed, shale mostly intervenes.

12°. Impressions of plants, particularly of the cryptogamic and culmiferous kind, are most frequently found in shale and bituminous shales that accompany coal, or which are found in coal mines, sometimes on sand stone, but very rarely on the coal itself. Roots also frequently appear in the indurated clay. Trees carbonated, or bituminated, sometimes repose on coal, or are found under it. Fluviatile (or river) shells, muscles, and land-snails, often occur; sea-shells seldom.

13°. Argillaceous iron ore is sometimes met with among the carboniferous strata of an argillaceous soil; and martial pyrites, either found, or much oftener oxygenated, and mixed with the substance of the coal.

14°. The *stretch* or *course* (drift, run) of seams of coal, and of their attendant strata, is commonly between E. and W. or N.E. and S.W. There are, however, a few exceptions to this rule.

15°. The *dip* (or pitch) of coal is exceedingly variable, sometimes nearly horizontal, sometimes from 25° to 45°, sometimes 75°, rarely approaching still more to the perpendicular.

16°. The uniform course (or plane) of seams of coal, and of the strata that accompany them, is frequently interrupted by obstructions, called *slips*, *dykes*, *troubles*, *faults*, (hitches, traps, breaks, fissures, loads, knots). These never fail to elevate (rise, upcast, uptrap) or depress (sink, downcast, downtrap) the strata beyond them; or rather, the strata on each side of them are found at different heights. This observation is general, being found to hold good in every part of Britain, as well as on the continent. The inequality of the height amounts from a few inches to 120 feet, but so great an inequality is rare, and has been found only in Derbyshire. In Germany it seldom exceeds, and scarcely amounts to, 50 feet.

17°. It has been observed in Britain, that if the *slip*, &c. overhangs (hades) on one side, and consequently forms an acute angle with the seam of coal which it cuts, the continuation of the stratum will be found *lower* on the other side of the slip, and consequently, *vice versâ*, if it recedes from (underlays), or forms an obtuse angle with the seam of coal on the one side; the continuation of the seam will be found higher on the other side, as in *Plate* I. *fig.* 1. of *Geology*, where *a* and *b* denote the interrupted seam of coal, and *c c*, the obstruction or *slip*, &c.

18°. These *slips*, &c. (or the matter filling them) sometimes consist of indurated clay, sometimes of sand-stone, both different from such as form the strata, but more frequently of some species of stone that never compose the strata of coal-mines, except, perhaps, rocks of the trap species; their thickness amounts in various mines, from a few inches to several yards. Nodules of coal are sometimes found in the slips, and water is frequently lodged in them. They often descend from the surface to the greatest known depths.

19°. The disposition of the strata below the surface seldom conforms to the figure of the surface. The former is often regular, when the latter is broken and uneven, and *vice versâ*; very frequently the strata dip into a hill, against the rise of the surface, or cross it in a right or diagonal line.

20°. The deepest mines known are those of Namur, some of which are said to descend 2400 feet, or 400 fathoms.

21°. The seams of coal, where in contact with their *roof*, *floor*, or *slip*, have a smooth, polished, glistening surface, which shews they were originally soft.

To the above we have, in parenthesis, added several synonyms for rendering them more intelligible in different districts; we subjoin other general conclusions of this ingenious author, relative to coals, with occasional synonyms of our own, and number them in a series following the above, for the convenience of reference: *viz.*

22°. That the quantity of earthy or stony matter in the most bituminous coal, bears no proportion to the weight of that coal; bituminous coal is capable of being charred (see COKE); and then it is a substance almost entirely resembling vegetable charcoal, which, on combustion, scarcely leaves $\frac{1}{70}$th of its weight of argil or stony matter. Geol. Ess. p. 316.

23°. That mines of *wood-coal* (brown-coal, Bovey-coal, surturbrand) have no uniformity in the thickness of their seams of wood-coal (as in § 4°); on the contrary, in the most considerable of these, an uniform decrease of thickness from the place in which the wood was first heaped, is observed. Ibid 321.

24°. That seams of real mineral coal, and those of earth or stone that accompany them, are observed to preserve their parallelism (noticed § 8°) even after an interruption by a slip or dyke, whether elevated or depressed. But in mines of wood-coal, no such parallelism, nor even any distinct number of strata prevail, but the whole appears to be one stratum, irregularly divided by masses of clay or stone. Ibid.

25°. That mines of wood-coal present sudden elevations or depressions in the same stratum; mines of real mineral coal never. Ibid 322.

26°. That there are no flips or dykes in wood-coal mines; those of genuine coal abound in them. Ibid.

27°. That wood-coal is frequently covered with round fragments of quartz; genuine coal never. Ibid.

28°. That there is in the museum of Florence, a cellular sand-stone, the cells of which are filled with genuine mineral coal. Could this have been wood? Ibid.

29°. That genuine coal is seldom found in plains, but wood-coal frequently is, according to Voight Pract. Ibid. 323.

30°. That the impressions observed on real coal, are those of herbaceous plants, as fern, &c.; the impressions of resiniferous plants have never been discovered on the strata that accompany coal, and the trees found are commonly birch or oak. Ibid. 318.

31°. That the traces of land vegetables, and not of marine vegetables, are found on the strata that cover seams of coal, or on those on which these seams rest, or on both. Sea-shells are scarcely ever found among them, and much less the bones of fish: that, on the contrary, reeds or rushes, and fluviatile shells, have been found in the strata that cover coal. Ibid. 325.

32°. That common salt is never found in coal-mines, except when in the neighbourhood of salt springs; but on the contrary, alum and vitriol. Ibid. 324.

33°. That carbonaceous strata never present a conic elevation on both sides of a disruptured stratum, as would be the natural result of an impression from below. Ibid. 337.

34°. That coal is never to be expected in primeval mountains, as granite, gneiss, &c., but that on the sides of these, particularly if very high, or in the hanging level that slopes from them to some river or valley, it may be sought. Ibid. 347

35°: That there is still a greater probability of finding it in the neighbourhood of mountains of argillaceous porphyry. Ibid.

36°. That it may be sought with probability of success in sand-stone mountains, if sand-stone and clay alternate, or sand-stone, clay, and argillaceous iron ore. Ibid. 348.

37°. That in any elevated land in which sand-stone and shale with vegetable impressions, or indurated clay and shale, or bituminous shale, form distinct strata, or clay, iron ore, and shale, with or without strata of sand, coal may well be expected. Ibid.

38°. That if sand-stone be found under lime-stone, or if they alternate with each other, and, particularly, if indurated clay and shale form any of the strata, they afford a probable indication of coal; otherwise coal is very rarely found in, or under lime-stone. Ibid.

39°. That coal is very seldom found with argillite, and such as has been is of the uninflammable kind. Ibid.

40°. That where trap, or whin and clay alternate, and more especially trap and sand-stone, coal may be expected; it is often, but not regularly, found under basalt; wood-coal is sometimes found under both. Ibid.

41°. That coal frequently bursts out on the surface, or on the sides of hills, in a withered state, which diffuses itself to a distance from its origin, and requires an experienced miner to trace it truly to the seam to which it belongs. Ibid.

Such are the valuable observations of Mr. Kirwan, on the probable existence of coal in certain situations, and on its position and relation to the adjoining strata, &c. These observations are for the most part unexceptionably true, and will be found consistent with what we have delivered on this subject, under the article COAL; but a few of them seem to require some remarks in this place.

§ 3°. Under the names of different collieries we shall take occasion to mention such seams of coal as are remarkable for their thickness, or other properties. The limitation of two miles, as the extent of regularity in coal seams, mentioned in § 4°, seems inconsistent with the multiplied observations of Mr. Smith and other recent observers; sometimes two or more veins of coal which are separated only by thin beds of shale, or other bituminous matter unfit for use, are found to unite, owing probably to the diffusion of the earthy matter more generally among the coal, instead of its forming distinct layers therein; but generally, in pursuing the seam further, the coals separate again; the extremities of a coal soil, can, in our opinion, only be found in the regular ending or out-crop of the measures, (see *Ending of* STRATA); or, where the strata on one side of an obstruction or fissure have been carried away by an abrasion or denudation of the elevated strata, of which we shall give some account, and mention several curious instances in England, under the term DENUDATION. We are not inclined to think, that thick intervening measures are more likely to alter the parallelism of seams of coal, as mentioned § 8°, than thin ones; the contrary opinion has probably in some cases arisen from comparing the seam on different sides of a fault or fissure, which hades or declines considerably from a vertical position. Under the article COAL, we have explained how different borings or sinkings in the same district, may differ materially, or perhaps entirely, owing to one being begun higher up on the measures or series of strata than the other, otherwise, we believe, that *the same* stratum will be found to have the same succession of strata under it. And here it may be necessary to note, that a place being *higher up* on the series of strata, has no relation to its actual elevation compared with the centre of the earth, or with a level line, as truly observed by Mr. Whitehurst, (Enquiry p. 153,) but the lowest known strata in many districts are seen on the greatest heights; this we shall amply illustrate by examples, in the progress of our work. See *Order of the* STRATA.

The semiprotolite, mentioned § 11°, certainly has no existence in a large portion of the British coal-mines, if it exists in any of them; the theory adopted by our author, of granite forming the foundation in every instance, and generally with a breccia or semiprotolite upon it, is disproved in innumerable instances by Mr. Smith's maps and sections, shewing the actual succession of strata throughout the country.

We are of opinion with M. Blumenbach (Hanbuch der Natur. Gesch 703), that most, if not all, of the vegetable fossil remains are *incognita*, and cannot be identified with any recent or known plants of the present race (§ 12° and 30°). The recent determinations of M. Cuvier declaring most of the osseous remains from the strata, hitherto discovered, to be *incognita*, will probably, we think, when the proper distinction is made between the regular strata fossils, and those which ought, according to our remark under the article COAL, to be considered as *gravel*, as *recent*, or as *peat* fossils, be much further extended, perhaps so far as to include every animal remain which is found actually lodged in the strata; the distinction, therefore, between *river* shells and *land* snails as accompaniments of coal, nearly to the exclusion of *sea* shells or marine remains, we consider a mere hypothesis, as we shall take future opportunities of shewing.

It is not universally true, as mentioned § 16°, that *slips*, *dykes*, &c. never fail to elevate or depress the strata, or to occasion an inequality in their levels; (see our description of dykes in the article COAL); the instances being numerous both in the coal measures and other strata, where a fissure of considerable width makes no sensible alteration in the continuity of the planes of the ruptured strata. The alterations of level which fissures occasion, are also much greater in numer-

ous instances, than our author admits; besides those mentioned, (COAL), we might state on the authority of Mr. Martin, that down-casts of 40 to 100 fathoms are not uncommon in the strata of what he denominates the Mineral Bason of South Wales. (Phil. Trans. 1806. p. 342). That the dislocations of the strata (§ 17°) have been gentle and gradual, (Geol. Essays, 333), we cannot suppose, much less that the extraneous matters which fill the fissures (§ 18°) were of prior origin to the strata themselves, and occasioned the overhanging or hading of the fissures, as our author has supposed, page 334. We have reason to hope, that these and several other hitherto unexplained phenomena of the strata, will be fully made out by the new lights which we shall be enabled to throw on the subject, arising out of the discoveries of Mr. Smith, above alluded to.

That some rare instances have occurred of the strata underneath, dipping in a contrary direction to those near the surface, § 19, must be admitted, and of which the Somersetshire coal-mines described in the Philosophical Transactions, N°. 360 and 391, by Mr. John Stracey, seem an instance; but in general it will be found, that the plane of the strata beneath, conforms to any *regular plane* which is to be found on the surface, either of a hill or vale, excepting only in the first case, instances where a perfectly straight and smooth fracture of the strata has happened, and, in the latter case, where stagnant water has in times long posterior to the formation of the strata, made deposits of mud, &c. in regular horizontal layers, or nearly so. This circumstance is of the utmost consequence to be attended to in tracing the strata of a country, as also to note carefully the distinction between these original planes or facettes of a hill, and the curious curving surfaces occasioned by the ending of strata, or the less regular curving of the surface, occasioned by the fracture (generally oblique or hading) and subsequent abrasion or rounding of the top and edges of the strata by the action of most violent currents of water. The circumstance mentioned by our author, of the strata dipping into a hill, is observable at the endings of most of the strata, and on the ruptured side of a large portion of hills and mountains, where the break or fissure occasioning the hill was in the run or course of the strata, as it lies at present, which, according to the observations of Charpertier, p. 80, is very generally the case; but where the present dip is in the direction of the fissure, or is inclined in any acute angle thereto, the strata will cross the rise of the hill, direct or obliquely as the case may be.

The probability will be shewn hereafter, that some of the disturbances, or ruptures in the strata, have been confined to a certain number of the upper strata, without affecting those below, and hence regular strata may sometimes be found, under those which are broken and uneven, as mentioned in this section; and the Somersetshire coal strata above mentioned may perhaps thus be accounted for. We have never been able to discover any thing, in the upper or under surface of a seam of coal, which demonstrates its having originally been soft, as mentioned § 21°; the glistening appearance of the surface in some partings, shews only the great regularity and truth of the planes or lamina, in which the strata were at first deposited. The polished or rather rubbed surfaces of the slips or dykes in coal-mines, and indeed in the strata generally, is a circumstance which seems most surprisingly to have been overlooked by writers on this subject. Mr. Kirwan only gives it the cursory notice contained in § 21°. This rubbing seems to have arisen from violent mechanical pressure, and motion to and fro against each other, and this seems not confined to fissures or joints, where the strata are lower on one side than on the other, so as to be explicable, as the effect of the slip, or mere sinking down of one part, when in close contact with the other; but this apparent wear in the surfaces, of even the smaller fissures, is as observable in marl and chalk pits, and all tolerably soft strata, where no alteration of the level of the strata has taken place, as where such depression of one side of the fissure is visible. See Philosophical Magazine, vol. xxv. p. 45 and 46, and vol. xxviii. p. 120. See also *Elevation of* STRATA. The facts and observations of Mr. Kirwan on coal, in sections 23° to 25° above, agree with our remarks under the article COAL, on the unequal and apparently accidental diffusion of the wood-like substances which have formed the strata, or rather accumulations of wood-coal. That slips or dykes have never been observed in wood-coal mines, (§ 26°), can only, we think, have arisen, from the limited extent of these accumulations in the strata, at least of such as are worked; while the excavations in the planes of the strata, as well as vertically in shafts, have been incomparably greater in the proper coal districts, than in any other, and therefore it is, that the dykes &c. have there been best ascertained; and from coal-working it has been, that almost all our knowledge of the strata has been derived; they were the objects which first awakened Mr. Smith's attention to the subject of the stratification, and by observations in the next most extensive field for these observations, *viz.* the cutting of navigable canals, he was enabled to generalize and extend the important facts, at present so little known, but to coal-miners, within their own particular district.

Genuine coal is now very seldom worked at its out-crop, as before observed, owing to the superior quality of the same seam, when deeper covered; but wood coal is generally worked so near to the surface, as to be opened at top, or uncallowed, instead of being mined for; it is no wonder therefore that gravel has been observed in contact with it, as observed § 27°.

Perhaps the specimen mentioned § 28°, did not contain genuine coal in its cells; we conjecture this, from having seen specimens of a reddish soft sand-stone, which Mr. Farey brought last summer from the foot of the cliff on the sea beach, about two miles east of Hastings in Sussex, from the vicinity of a cottage called the Grovers, which contained so many detached pieces of bitumenized wood, that were an augre-hole to be bored into it, and supplied with water, &c. something like the appearance of penetrating a coal vein, might be had in the borings; and it is this stratum, dipping under Bexhill, situate about 6¼ miles to the westward, which in the opinion of Mr. F. has been there mistaken in the borings for a seam of coals, but which the improved boring apparatus of Mr. Ryan, mentioned under COAL, would have detected, and saved, perhaps, a most unparallelled waste of money, in the measures now pursuing.

The remark in § 29°, that genuine coal is seldom found in plains, is by no means true; the coal-strata about Bedworth in Warwickshire, Whibsey Slack near Bradford in Yorkshire, and numerous other places which we could mention, form extensive plains; a contrary remark to the above, would perhaps be much nearer to the truth.

It will readily be gathered, from our remarks on § 12°, that we have our doubts, on the distinctions between resiniferous and non-resiniferous plants, land and marine vegetables, and river and sea shells, as accompaniments of coal, § 30 and 31, and that we incline to the opinion, that further searches will class all or most of them among the incognita of a prior state of aquatic existence.

Impressions from below the strata § 33, especially from elastic fluids, must have formed conic elevations or craters in making their escape, and could not have produced that universal breaking of the strata which we find; which is indeed so universal, that a single acre of the surface can scarcely be

found without one, and sometimes numerous fissures through it, although the original plane of the strata is still maintained by its fragments, facts which had a material influence on the writer's reasonings upon this subject, which we have hinted at above. The seven following sections being stated, as consequences of Mr. Kirwan's particular tenets, which we shall mention presently, on the origin of coal, we shall pass them without comment for the present, and proceed to state the principal among the various opinions which have been given, on the origin of the invaluable substance, which is the subject of our present inquiry. In stating the opinions which have been held as to the origin of coal, we shall begin with that of Arduino and some others, who have supposed coal to originate from the fat and unctuosity of the numerous tribes of animals which have peopled the ocean; which matter being accumulated on the bottom of the sea, became covered by various strata, in consequence of the different changes which the surface of the earth and bottom of the seas have undergone. The most obvious objections to this hypothesis arise, from the total dissimilarity of coal to animal fat, and the levity of the latter compared with water, which should have occasioned it rather to rise to the top of the water and float, than to dispose itself in such extremely regular beds at the bottom, as to form strata of coal. The existence of a few shells in or near to coal, in some places, which resemble some of the recent sea shells, we conceive to be as far from proving it to be of marine origin (as contended by the author of this hypothesis) as the supposed resemblance of ferns, reeds, rushes, &c. and land and river shells, with the absence of bones of fish and sea salt in other places, proves it to be of land origin, § 30 and 31 of Mr. Kirwan's observations above, and Geol. Ess. 323.

The next opinion which we shall mention is that of M. Gensanne and others, who, from the specific gravity and hardness of some kind of coal, and its large quantity of bituminous matter, have concluded pit-coal to be a peculiar earth of the argillaceous genus, penetrated and impregnated with petroleum. To this opinion Mr. Kirwan opposes the remark in the 22° § above, and adds, that some known species of coal, that of Kilkenny for instance, contain no petrol or other bitumen in their composition, and are thence called natural carbon. See Mr. Kirwan's Mineralogy ii. 49.

M. Tingry, Dr. Darwin, and others, have imagined, that heat generated by the fermentation of immense beds of vegetable matters, have distilled or separated there from the oils, naphtha, asphaltum, &c. which condensed between the strata, and have formed seams of coal, and bituminous schists. On this fanciful theory it can scarcely be necessary to comment.

Dr. Hutton imagines coal to be formed by the slow depositions of oily and bituminous matters at the bottom of the sea, which matters he supposes to have originated in the dissolution of the various animal and vegetable bodies, which are continually perishing on the surface of the earth, and in the waters of the ocean. The fuliginous matter which is separated during the combustion of various bodies on the surface of the earth, he supposes, is washed off the surfaces on which it falls by the rain, and, being thus made to flow into the rivers, is carried off by them into the sea; where it also adds, by its deposition, to the mass which is accumulating at its bottom. Another source whence he supposes this matter to be derived, is the water draining from peat mosses, which, according to his ideas, is charged with bituminous matter, very much resembling fossil-coal, when precipitated. The depositions of these matters in the sea are supposed by the Doctor to be so regular, as to produce strata, which, becoming covered by an immense weight of superincumbent earth, must thereby become exceedingly compressed and condensed, and finally consolidated, by the powerful influence of subterranean heat; and ultimately, by the progressive change of sea into dry land, these become seams of coal, such as we now find in the bowels of the earth. Granting that oily and bituminous matters are thus conveyed by the rivers into the sea, but which Mr. Kirwan has shewn does not take place, there is a manifest absurdity in supposing these matters to sink to the bottom of the water; while it is scarcely possible to conceive, that distinct beds or strata of coal and earth, especially such regular and extended ones as we find of them, can be formed by deposition in an ocean constituted as our present one is. The operation of heat upon these coal strata has been shewn by Mr. Kirwan and others, to be inconsistent with all the circumstances attending them. It is true that sir James Hall (Transactions of the Royal Society of Edinburgh, vol. vii.) has endeavoured to remove the force of these objections, by shewing, in the detail of his chemical experiments, and by the specimens presented to the British Museum in June 1806, that wood, or even horn, may be converted to a substance resembling coal, by the action of an intense heat applied under a very immense pressure. Valuable and satisfactory as we think sir James's experiments to be, in proving the possibility of carbonat of lime being fused without decomposition, and of vegetable and animal substances being melted or reduced to a coal-like substance, under the heat and confinement, as well as pressure which he applied, yet we think, the difficulty of Dr. Hutton and other Plutonists to be still nearly as great as ever in shewing, that such a degree of heat ever has existed in strata, not obviously volcanic; certainly, lava, however hot we may admit it to have been, could never by its mere protrusion under beds of sea-shells, as sir James Hall endeavours to explain, in his imaginary section of a volcanic mountain and adjoining sea, (*fig.* 41. in the Transactions,) have heated their whole mass, in the degree which his own experiments have shewn to be necessary for the formation of lime-stone; nor is it conceivable, that the supposed superincumbent strata, much less any depth of water, could have so effectually retained the carbonic gas, as he himself has shewn to be necessary, to form lime-stone or marble out of shells or chalk; or the other gasses, so as to effect the conversion of wood and vegetables into pit coal.

The ingenious Mr. Kirwan supposes, that a large class of primeval rocks and mountains, containing carbon and petrol in their composition, have been either totally destroyed, or their heights and bulk considerably lessened by disintegration and decomposition; and that by the equable diffusion of the disintegrated particles, successively carried down by the gentle trickling of the numerous rills that flowed from those mountains, the seams of coal and their attendant strata were formed, in lakes at their feet, we suppose, but this circumstance it is difficult to gather from Mr. K's account; according to which, the decomposed feltspar and hornblende formed clay, the particles of bitumen were set free, and these, when united, sunk through the moist pulpy, incoherent, argillaceous masses, and formed the seams of coal beneath them. Mr. Parkinson (Organic Remains I. 248.) has commented on the absurdity of such a light substance as bitumen, being supposed to descend through a pulp of argillaceous matters, and deposit itself in a stratum below it.

The next hypothesis which we have to mention, and which has numerous adherents, ascribes the formation of coal to forests of antediluvian trees, and to peat bogs, and other vegetable productions of the dry land of that period, buried during the supposed violences of the Mosaic deluge, under the strata which are found covering

them in the ſtate of coal at this day. This hypotheſis we ſhall examine, and ſtate ſome of the objections to which it ſeems liable; and firſt, they are mines of wood-coal, deſcribed in §s. 23° to 29° above, which alone have the appearance of being formed by depoſitions of floating wood and other matters, in the irregularity of their extent, and the variable thickneſs of the ſeam, circumſtances extremely rare in regular coal-ſeams, or in the matters alternating with them. Some, we are aware, have contended, that this uniformity in the thickneſs of regular coal ſeams has ariſen, from the maſs of depoſited wood and vegetables having, ſince they were covered by the ſuperincumbent ſtrata, been liquified, or nearly ſo, by ſome proceſs, the exact nature of which has never been agreed upon by the advocates of this hypotheſis, and that in this ſoft ſtate (§ 21° above) they were preſſed into an uniform ſeam, or continued ſtratum. An obvious objection to this explanation, of the uniformity obſerved in the thickneſs of a real coal-ſeam ariſes from the fact, that all coal-ſeams preſent themſelves at the ſurface in the endings of the ſtrata, and frequently alſo in the ſides of hills, occaſioned by diſlocations of the ſtrata (§s. 19° and 41°); and here it will be difficult, if not impoſſible, to conceive, how the coal, when in a ſoft ſtate, was prevented from ſqueezing out by the weight of the ſuperincumbent ſtrata, and forming maſſes of that ſubſtance at the ſurface, of which no traces are obſervable; for, the diffuſion of the withered coal or ſmut, below the out-crop of coal ſeams (§ 41) has no ſuch appearance, but in all its circumſtances agrees, with the withered remains or rubble of other ſtrata at their outcrop. We incline to the opinion, that real wood, or other recent vegetable ſubſtances, have never been found in the coal ſeams, or in their accompanying meaſures or ſtrata: a large portion of the bitumenized vegetable impreſſions there found certainly bear no reſemblance to known woods, or plants of the preſent race; while moſt, if not all of ſuch remains, that have been denominated after recent plants, have been ſo named without that care which a botaniſt would exerciſe, in claſſing or naming a new recent plant which was preſented to him for examination. Hence the ſuppoſed reſemblance to land plants, rather than to aquatic plants in theſe curious remains, has, as we conceive, ariſen. Our next objection to the above hypotheſis is founded, on the improbability of the accumulation of ſuch immenſe quantities of trees and vegetable matter in the antediluvian world, in leſs than 17 centuries, when more than 42 centuries ſince have accumulated ſo little: if they had remained on the ſurface of the dry land and not decayed, a very large portion of the earth muſt have been thereby incumbered and rendered unfit for the habitation and uſe of men or animals; it is highly improbable, that they were progreſſively removed from the dry land to the antediluvian ſea, and there preſerved until the deluge. The probable quantity of growing trees and vegetables exiſting at the commencement of the Moſaic deluge, ſeems quite inſufficient to account for even the Britiſh coal ſtrata, when it is conſidered how much the bulk or maſs of the vegetable matter has, in all probability, been reduced, by its converſion into real coal: and this laſt ſuppoſition is alſo denied us, by the Moſaic account of this event, from which (Geneſis, vi. 7. 17. 19. 20; vii. 2, 3, 4. 8, 9. 14. 21, 22, 23; viii. 11. 17. 19; ix. 3. 20.) we gather, that the exiſting trees and vegetables (as well as fiſh) were not deſtroyed by the deluge (See DELUGE.) Some writers on the formation of coal have ſpoken of it, as the remains of vegetable matters, either growing in, or that were depoſited in the ſea, in very diſtant periods, and which have been immured under layers of earth, &c. by certain convulſions and deluges (whether the Moſaic or others, ſome of them have not explained) which have ſince occurred: inſuperable difficulties will, we apprehend, be found to attend any hypotheſis, which ſuppoſes the burial of the matters compoſing coal, at any period ſince the earth has been divided into ſea and dry land as at preſent, let the origin of thoſe matters be ſuppoſed whatever they may.

The writer of this article begs leave to ſtate another opinion, which the recent diſcoveries of Mr. Smith and himſelf ſeem to render, in his judgment, moſt probable, on the origin of mineral coal. This writer has ſeveral times taken occaſion to mention the probability, that the ſurface of the earth, and as far below it as concerns us at preſent to conſider, originally conſiſted of parallel laminæ of different matters, not concentric to the earth, but inclined, or dipping towards the eaſt, and ending towards the weſt; each ſucceeding lamina, in aſcending the ſeries, being generally ſhorter towards the weſt than the eaſt, in the ſame manner as the very minute laminæ of cryſtals are now admitted to be, and thereby to form the ſlope, or inclination of the cryſtalline ſurface; but with theſe differences, that the laminæ of the earth, or the different ſtrata were diſpoſed to form indented or fingered endings, inſtead of the ſtraight lines ſo generally aſſumed in cryſtals of a ſmall ſize, and that the terreſtrial laminæ are of very unequal thickneſſes. Various circumſtances, beſides the immenſe maſſes of unbroken ſhells and other matters nearly ſimilar to the ſea ſhells, corals and other marine productions of the preſent time, ſhew theſe ſtrata to have been depoſited under quieſcent and probably very deep water, anſwering, as he conceives, to the ſtate of the earth as deſcribed by the ſacred hiſtorian, prior to the ninth verſe of the firſt chapter of Geneſis, or in the two firſt grand periods metaphorically called days, after which God ſaid "Let the waters under the heavens be gathered together into one place; and let the dry land appear." Abundant evidence will, as he apprehends, be furniſhed by an examination of the various organic remains lodged in or between the ſtrata, that the animals, at leaſt thoſe of the teſtaceous, cruſtaceous, and zoophytic kinds, whoſe remains they are, lived in the particular places where each is now found, at the time that the ſtrata, on or in which they are lodged, formed the bottom of the univerſal ocean above-mentioned; each newly depoſited ſtratum being a proper nidus for the production, and probably a pabulum for the nouriſhment of the animals peculiar to it, and which apparently in moſt inſtances ceaſed to exiſt, when new matter in proceſs of time began to be precipitated, for the production of a new ſtratum upon the former one, which, alſo, in turn had its own peculiar animals, as their remains in ſuch numerous inſtances teſtify.

The opinions of that able naturaliſt, M. Cuvier, in his recent report to the national inſtitute of France on the tranſactions of that learned body in 1806, are in favour of the animal incognita of the ſtrata, having lived where their bones are now found: and from an examination of the accounts from more than 600 places, where bones reſembling thoſe of elephants and rhinoceroſes have been dug up, belonging principally to the claſs of *gravel foſſils*, we believe, this able anatomiſt is of opinion, that all theſe differ eſſentially from the recent animals of theſe kinds and are of ſpecies now quite extinct.

Apparently, after long periods of ſucceſſive depoſition and animal exiſtence, ſuch ceaſed for a time altogether, or nearly; and the ſtrata produced an immenſe variety and quantity of vegetables, moſt of them quite unlike the vegetable tribes of the preſent race; the immenſe foreſts

of weeds which have been discovered at the bottom of the present ocean, in some places, probably bear no proportion to the thickness and magnitudes of many of these vegetable productions of the primitive or universal ocean, as some of them probably exceeded our trees in size; their arboriferous trunks, so closely imitating wood, as not hitherto to have been distinguished therefrom; but the greater part of the vegetables appear to have been of a small size, especially on strata, which seem to have been depositing so fast as to have immured them singly, as is often the case with the bituminous or coal shales, mentioned under COAL, of which the most beautiful, various, and minute specimens, might be obtained in many coal workings. The successive depositions in these vegetable, or carboniferous soils, appear to have differed, as we have stated those of the animal, or epizootic, to do, in their fitness for producing different kinds, and a similar appearance and disappearance of different vegetable remains will be observed, in examining a series of coal measures, or strata, upwards or downwards; and, often, strata will be found intervening such, which contain no vegetable impressions, but in some rare instances, those of animals will therein be found, which observations, of too limited an extent, as we suspect, have denominated land and river exuvia, § 12° and 30° above.

It is to beds of sub-aqueous vegetables, such as have been mentioned above, uniformly and thickly covering large extensions of the planes of strata, if not their whole extent, that the writer of this article can alone look, in his view of the subject, for the true origin of vegetable coal; and according, perhaps, to the nature of these vegetables, as well as to the kind or quantity of the mineral deposits, made during their growth, will the quality of different seams of coal be found to vary, while their different thicknesses has depended, on the quantity of vegetable matter accumulated, either dead, as in our peat bogs, or then actually growing, when a deposition began to happen, either so copious or different, as to put a period to their growth, and ultimately to immure them. That vegetable impressions are rarely found in the substance of a coal-seam, as remarked by Mr. Kirwan in the passage (§ 12°) above quoted, may, we think, be perfectly accounted for, when the peculiar kind of crystallization, which all good mineral coals seem to have undergone, is taken into consideration; a change which seems to have effectually destroyed the organization of the plants composing the coal, but without a liquefaction having happened, as in some stony crystallizations, which have of late years been noticed by mineralogists.

Mr. Parkinson endeavours to account for this change, which vegetable matters undergo in passing into coal (Organic Remains, p. 253.) by a process which he calls *bituminous* FERMENTATION, which see. According to the observations of this gentleman, fossil coal has also, in this change, had numerous septa, or thin fibres of uninflammable matter, interposed between the particles of pure bituminous matter, of which it principally consists, which has modified its inflammability in the degree which renders pit coal so well fitted for the purposes to which it is applied. In the specimens which Mr. P. examined, the inclosed particles of bitumen were in form of rhomboids, or parallelepipeda, and the separating pellicles, or septa, were formed of sulphate of lime, containing a small portion of alumine, and sometimes of sulphuret of iron also. Organ. Rem. 269.

The new opinions which we have ventured to present, if such they are, relating to the origin and formation of coal, in that and the present article, will, as we trust, be candidly received by our readers, and submittted to that sovereign test, an unprejudiced comparison with the phenomena, by which it is our sincere wish that they should either stand or fall, as it is also of the gentlemen above alluded to, through whose valuable labours and communications, we were enabled to give them.

The most remarkable colliery, or coal-work, that we have ever had in this island, was that wrought at Burrowstonness, under the sea. The veins of coal were found to continue under the bed of the sea in this place, and the colliers had the courage to work the vein *near half way over*; there being a *mote* half a mile from the shore, where was an entry that went down into the coal-pit, under the sea. This was made into a kind of round key, or mote, as they call it, built so as to keep out the sea, which flowed there twelve feet. Here the coals were laid, and a ship of that draught of water, could lay her side to the mote, and take in the coal.

This famous colliery belonged to the earl of Kinkardin's family. The fresh water which sprung from the bottom and sides of the coal pit, was always drawn out upon the shore by an engine moved by water, that drew it forty fathom. This coal pit continued to be wrought many years to the great profit of the owners, and the wonder of all that saw it; but, at last, an unexpected high tide drowned the whole at once, and the labourers had not time to escape, but perished in it. Phil. Trans. No. 98.

Colour

COLOUR, or COLOR, from the Latin, *color*, in *Philosophy*, means that property of bodies which affects the sight only; thus the grass in the fields has a green colour, blood has a red colour, the sky generally appears of a blue colour, and so forth; nor can those colours be distinguished by any of our other senses, besides the sight. The variety of colours, as they are presented to us by the substances that

surround us, is immense, and from them arises the admirable beauty of the works of nature in the animal, in the vegetable, and in the mineral kingdom, or, more properly speaking, in the universe. The science, which examines and explains the various properties of the colours of light and of natural bodies, and which forms a principal branch of optics, has been properly denominated *chromatics*, from the Greek word, χρωμα, which signifies *colour*. We shall, however, state this theory in the present article, as being much more obviously recurred to by those persons who wish to be informed on the subject. A distinct idea of what is meant by the word *light*, may be easily formed by its contrast with darkness, which is a privation of light. With our eyes shut we have darkness; if we open our eyes, whatever we perceive through them is occasioned by the agency of light, and the various colours of bodies are parts of that light.—It has sometimes been pretended by certain ignorant persons, that they could distinguish colours by the touch; but the testimony of divers intelligent persons, who have had the misfortune of being blind, in consequence of which their touch has, from necessity, become very exquisite, has constantly contradicted those vain assertions. Besides, it will appear from the following theory of colours, that to discriminate colours by the touch is utterly impracticable. There are indeed certain pigments of common use in painting, which, either from their roughness, smoothness, unctuosity, or other quality, may affect the touch, and with a little practice a person may learn to distinguish the feel of vermillion which looks red from that of sap-green, which looks green, and so forth; but this is not the art of distinguishing colours by the touch. It is only the art of distinguishing certain peculiarities of surface. In fact if two pigments exactly of the same texture (and several such there are) but of different colour, be presented to the fingers of a man with his eyes shut, he will pronounce them to be exactly of the same colour.

The questions which naturally occur to the human mind in the contemplation of colours, are, whence do they derive their origin?—Are they produced by the coloured bodies themselves, or by something external?—Do they move from the coloured bodies to our eyes, and strike upon them, or enter them; or are they owing to some medium interposed between the various bodies of the universe?—Are they material or not?

The ideas entertained by the ancients concerning the nature of colours, were mostly wild and absurd; nor has the present theory, imperfect as it is, been formed without an innumerable variety of experiments, observations, and the concurring investigations of a great many ingenious persons. The followers of Pythagoras called colour the superficies of bodies; Plato considered it as a flame issuing from them; Zeno called it the first configuration of matter; and Aristotle said it was that which rendered bodies actually transparent. We need not add a formal refutation of those extravagant ideas, which were the mere offspring of the imagination, unsupported by experience and by reason. The philosophers of those times paid little or no regard to experiments; hence they made no discoveries or improvements worthy of being recorded. A long and unprofitable period of nearly 2000 years elapsed, from the commencement of philosophical studies in Greece, until about the time of Descartes, when the revival of learning in Europe renewed with additional vigour the enquiries concerning the nature of light and colours. And it is curious to observe by what small steps, and what circuitous ways, any useful discoveries were made. See Priestley's history of vision, light, and colours. Descartes considered colour as a modification of light, and he attributed the difference of colour to the prevalence of the direct or rotatory direction of light. Grimaldi, Dechales, and others, supposed that a certain elastic medium of a peculiar kind filled the universe, and that the differences of colour depended upon the quick or slow vibrations of that medium. Rohault imagined that the different colours were produced by the rays of light entering the eye at different angles with respect to the optic axis. And Dr. Hook imagined that colour is caused by the sensation of the oblique or uneven pulse of light; which being capable of no more than two varieties, he concluded there could be no more than two primary colours. Such were the ideas of philosophers respecting the nature of colours, when Sir Isaac Newton began to examine the subject in his cautious experimental manner, by which means, about the year 1666, he discovered the foundation of a theory of colours, which has been justly adopted and admired by his contemporaries, as well as by the present succeeding generation.—Rays of light issuing from a luminous object, proceed in straight lines as long as they pass through a uniform medium. If they meet with a transparent medium of different density, they will also proceed through it in straight lines, provided they enter that medium in a direction perpendicular to its surface, otherwise they are caused to bend their course, so that beyond the abovementioned surface they proceed in straight lines also; but these straight lines form a certain angle with the straight lines of their direction before they entered the last medium. The bending of the rays is called the *refraction* of light, and the angle that has been just mentioned is called the angle of refraction. See REFRACTION. Newton, having presented a glass prism, or kind of wedge, to the light of the sun, which entered a dark room through a small hole, found not only that the rays were bent from their course, *viz.* refracted, but he likewise observed that the image of the sun was thereby considerably elongated; and this elongated image instead of appearing of a uniform bright white light, was resolved into a series of colours, which exactly resembled the colours of the rainbow. This elongation of the solar image thus formed, is called the dispersion of light. These colours pass from one to the other by very small, and altogether imperceptible gradations; so that it is impossible to say where one begins and the next ends. Various methods have been tried for the purpose of rendering the colours of this prismatic spectrum more limited and distinct; none, however, has been attended with complete effect. The following seems to be the best method. Let the light of the sun pass through a hole of about one-tenth of an inch in diameter, into a dark room. Place a screen at a little distance from the hole (for instance six or seven inches) within the room, and let the middlemost part of the light pass through a similar hole in the screen; the object of which is to prevent, in great measure, the scattered light or penumbra, on the sides of the spectrum. Let the light then fall perpendicularly upon a convex lens; at the distance of about 10 feet, by which means a defined image of the sun will be formed upon a screen placed at the focal distance of the lens. Now, if a prism be placed close to the lens, so that the light, after having passed through the lens, may pass through, and be refracted by, the prism; then a coloured spectrum will be formed upon the screen. The long sides of this spectrum are very well defined; but its narrow terminations are semicircular, and its whole length consists of circular coloured images of the sun intermixed with each other, especially about the middle or axis of the spectrum; yet the most predominant colours are more distinguishable from each other, especially towards the sides of the spectrum, so that their boundaries may be marked with tolerable accuracy. The glass prism fit for this experiment must be well formed,

and free from veins, fcratches, bubbles, &c. Thofe principal colours are feven in number, *viz*. red, orange, yellow, green, blue, indigo, and violet. They do not occupy equal fpaces in the fpectrum; but for the proportion of their breadths, and likewife for a more accurate defcription of the prifmatic experiments on light, fee the article REFRACTION.

The above defcribed experiment with the glafs prifm gave fir Ifaac Newton reafon to conclude that the white light of the fun confifted of feven colours, which had different powers of being refracted, fo that the red rays were refracted lefs, the orange a little more, the yellow ftill more, and fo on; hence the image of the fun was converted into an oblong variegated fpectrum. In confirmation of this theory Newton inftituted a variety of other experiments, which were attended with remarkable refults, and the principal of them are as follows:

If the light which has been refracted and difperfed by a prifm, be received again upon another prifm which muft be fituated in a direction perpendicular to that of the former; the fpectrum will by that means be removed from its original fituation into a lateral one; but its breadth and its colours will remain unaltered. Now if the elongation of the beam of white folar light, and its refolution into different colours, were a modification of light produced by the prifm only; then the fecond prifm ought to expand the fpectrum in breadth, fo as to form a quadrilateral figure of equal fides; but inftead of that we find that the colours and their breadths remain unaltered.

If the refracted and difperfed beam of folar light, be received upon a concave reflector, the different coloured rays will be reflected to a focus, where they will form a white or colourlefs image of the fun. But if any of the colours be ftopped by the interpofition of a wire, or other flender and opaque body between the prifm and the reflector, then the image will become coloured with fome mixture of colours. This proves that white light confifts of coloured rays, intermixed in a certain proportion, and that by a mixture of the rays of the feven primary colours in that due proportion, white light is produced. Therefore, white arifes from a certain mixture of colours, and blacknefs arifes from a ftoppage or abforption of all colours. This property of light and colours, may be familiarly illuftrated by the following experiment: Divide the flat furface of a wheel, or the upper flat furface of a top, fuch as boys ufe, by means of lines going from the centre to the circumference, into feven parts, having the fame proportion that the breadths of the colours have in the prifmatic fpectrum, and let thofe portions be pointed refpectively with the feven colours. This done, if you fpin the wheel or the top, fo as to caufe it to turn very faft, in the light of the fun; you will find that the painted furface will look white; for by the quick motion of the wheel, the impreffions of the colours in the eye become mixed, and of courfe they form a white light. Stop the wheel and the feven colours will appear very diftinct.

If, when a fpectrum is formed by the light which has paffed through a prifm upon a fcreen, a fmall hole be made through the fcreen, and the rays of one colour only be permitted to pafs through it on the other fide of the fcreen; then whatever is viewed in that homogeneous light, will appear of that particular colour. Thus, if the red light only has paffed through the hole, then blood, or grafs, or milk, &c. viewed in that light behind the fcreen, will all appear red; excepting that the blood will appear of a ftronger red colour than the grafs or the milk. If the blue light only has been tranfmitted through the hole; then the abovementioned fubftances will all appear blue; and the like muft be underftood of the other homogeneous colours. This proves that the colours, which feem to proceed from coloured bodies in general, do not belong to thofe bodies; but they are the component parts of the white light, in which thofe bodies are viewed, and that certain bodies have the property of abforbing fome of thofe coloured rays of the white light which falls upon them, and of reflecting others. Thus, grafs reflects the green rays and abforbs the reft, hence, the green rays coming to our eyes, render the appearance of grafs green; thus blood abforbs every other coloured ray excepting the red, and fo forth. Black bodies abforb all the feven coloured rays, and white bodies reflect them all.

If two holes, at about a foot diftance from each other, be made in the fhutter of a dark room, and two prifms be ufed, *viz*. a prifm be placed to receive the light at each hole, two fpectrums will thereby be formed upon the fcreen; and by turning the prifms gently round their axes, the fpectrums may be caufed to fall one upon the other. Let the yellow of one fpectrum fall upon the blue of the other, and at that place the mixture of thofe two colours will appear green. Let a fmall hole be made exactly at that place, and that green light will pafs through the hole behind the fcreen, and will form a green circular image upon another fcreen placed to receive it. Now, if exactly behind the perforation of the firft fcreen, you fix the refracting angle of a prifm, then the image upon the fecond fcreen will not only be moved from its place, but will appear oblong, with a yellow border at one extremity, and a blue border at the other extremity; for that fpot or image of the fun confifts of two primitive colours of different refrangibilities. The fame thing muft be underftood of any other colour formed from a mixture of any two primitive prifmatic colours; for any two of thofe colours will form, or rather will look like an intermediate colour; thus, red and yellow form an orange, blue and violet form an indigo, and fo forth.

If the experiment be performed with one folar fpectrum: *viz*. a fingle prifmatic colour; for inftance the green be permitted to pafs through a hole in the fcreen, and be then received upon another fcreen, the image will be of the fame colour as in the preceding experiment, *viz*. green, and circular. Now, by placing a prifm behind the perforation of the firft fcreen, the green image will be moved from its place, but it will not be elongated nor altered in colour, becaufe this image confifts of one uniform primitive colour. (Newton's Opt. b. i. p. ii. prop. iv.) This remarkable experiment fhews, that though a green may be formed from a combination, or any other prifmatic colour may be formed from a combination of the two adjacent colours; yet each of thofe colours in the prifmatic fpectrum, is a primitive uniform or homogeneous colour.

Notwithftanding the conviction which naturally attends the refult of the above-mentioned experiments, feveral perfons have fuppofed that the primitive colours of light are not feven, but three only; namely, red, yellow, and blue; and they have been led to this fuppofition, by obferving that the painters can produce all the other colours, by mixing either all thofe three colours together, or two of them, in due proportion.

A recent writer of eminence in the philofophical world, (M. C. A. Prieur) has ftarted another theory. He thinks that the primitive colours. (*viz*. the components of white light) are three in number; but he fuppofes them to be the red, the green, and the violet; and that the other colours of the fpectrum are formed from a mixture of thofe; that is the yellow from the red and the green, the blue

from the green and the violet, &c. See l'Annales de Chimie. Sept. 1806.

Hitherto we have treated of the formation of colours by refraction; from which it appears that the white solar light consists of coloured rays; that whenever that light enters a transparent medium in an oblique direction, it is caused to deviate from its rectilinear course; and at the same time its component coloured rays, are separated in consequence of their different refrangibility. The next series of facts, upon which the theory of colours depends, relates to the *inflection* of light, it having been found, that the rays of light are bent in their course, and resolved into their component colours, not only by refraction, but likewise by merely passing by the surfaces of bodies. It seems that the rays of light are attracted by bodies, when they come within a certain distance of their surfaces, and that the coloured rays of white light being attracted more or less, are separated from each other. A great variety of experiments relating to this inflection of light, were originally made by Newton, and have, since his time, been instituted by other able philosophers. But, though several remarkable facts have been discovered; yet the present state of knowledge does not admit of their being reducible to a single principle, or to any general and comprehensive laws.

In order to give our readers some idea of this property of light, we shall now subjoin an experiment related by a recent anonymous writer; referring, then, the reader to the article *Inflection of* LIGHT, for a full account of whatever belongs to it.

"Across a beam," says the above-mentioned author, "of solar light, admitted into a dark chamber, through a small hole in a thin piece of lead, nearly $\frac{1}{50}$ of an inch wide, I interposed a hair of a man's head, and receiving the beam on a screen, or sheet of white paper at a distance, and with an obliquity convenient for the purpose, I noted the following appearances.—At the termination of what may be considered as, and therefore may be called, a shadow, whose intensity or darkness was not considerable; the following orders and distinctions of colours appeared. First, and nearest to the dark or black parts of the shadow, might be seen a diluted blue, changing into a breadth of white light, followed by breadths of yellow and red. To these succeeded an interval of diluted shade, then breadths of diluted violet, blue, diluted green, yellow, red; then green diluted yellow, red; diluted green, red; white, diluted red; and finally white light. These are the more general orders of the colours. Of these orders, the three first were sufficiently obvious and distinct; the last evanescent and requiring accommodation of circumstances to produce, and attention to perceive them." Observations concerning the Inflection of Light, &c. London 1799.

The last set of facts that remains to be mentioned, as relating to colours, consists of the phenomena exhibited by thin transparent bodies, especially by those of variable thickness. Every person must recollect to have seen the bubbles of a solution of soap, or of other thickning substance, exhibit a variety of colours similar to those of the solar spectrum, or of the rainbow. These bubbles are nothing more than thin vesicles of the solution, whose thickness varies continually. But a variety of thin solid substances exhibit the like phenomenon, such as plates of muscovy glass, or of talc; thin plates of glass; metallic and glass plates moistened with a variety of fluids, &c. Newton took two object-glasses of telescopes, one of which was a plane convex, and the other a double convex one. He laid the latter on the flat side of the other, and pressed them gently. Instantly circles of colours appeared about the point of contact, which increased and decreased both in number and in size, according as the lenses were more or less forcibly pressed against each other. The central spot was black, and circles of colours appeared round this spot, which were brighter near it than farther off. Their order, commencing from the black spot, was blue, white, yellow, red; violet, blue, green, yellow, red; purple, blue, green, yellow, red; green, red; greenish, blue, red; greenish, blue, pale red; greenish, blue, reddish, white. (Newton's Optics, b. ii. p. 1. Observ. iv.) Experiments similar to the above have also been performed with flat glasses, lenses of various curvatures, and other substances, by other philosophers, such as Moraldi, Grimaldi, Delisle, Mairan, Mazeos, Du Tour, Muschenbroeck, &c. See an account of their experiments in "Priestley's Hist. of Vision, Light, and Colours." p. 6. sect. 6. After the above succinct account of the principal experiments that have been instituted, and the various important discoveries that have been made, concerning the nature of light and colours; it is proper to observe, that the subject is not only very far from being exhausted; but that the theory arising from those experiments and discoveries is doubtful in almost all its parts. The number of primitive colours distinct from one another, if such do really exist, is not quite determinate; the attraction between the rays of light and other bodies is an hypothesis not clearly understood; for it is a prevailing opinion with several philosophers, that the rays of light are attracted within a certain distance, and repelled beyond that distance. The reflection of coloured rays from the surfaces of bodies is likewise involved in much uncertainty; it being unknown whether the reflection takes place at the very surface, or at a little distance beyond it by some power inherent in bodies, or, lastly, from some other surface a little within the bodies, which supposition is founded upon the hypothesis that all bodies are transparent, as far as a very small part of their bulk, which hypothesis is founded upon the observation that several dense and opaque bodies, when much attenuated, become, in some measure, transparent; and such is the case with gold leaf, which, when placed against the light, appears of a greenish cast.

Notwithstanding this uncertainty respecting the theory in general, the following particulars seem to be sufficiently established; namely, that by refraction and inflection the white light of the sun is resolved into coloured light. Here it may be naturally asked whether the light of other luminous objects is not resolved, by the like means, into the same colours? The observations made in relation to this particular are not so numerous, nor so exact as might be wished; it appears, however, that some luminous objects yield rays of particular colours more abundantly than of other colours. The abbé Rochon having placed a prism before an achromatic telescope, observed through it the light of the stars; and found that the white light of Sirius was resolved into an oblong spectrum, which consisted almost entirely of three colours, *viz.* red, green, and violet. An indication of yellow was barely discernible between the two first, and a slight degradation between the two last. Through Dr. Herschell's powerful telescopes most of the fixed stars seem tinged with peculiar colours, *viz.* some evidently incline to a green, others to a red, and so forth. The light yielded by particular combustibles is also tinged with peculiar colours, and the flame of spirit of wine is a strong instance of this nature; for if common salt be mixed with the spirit, the light of its flame seems to be entirely destitute of red, yellow, and violet, and it is owing to this peculiarity that children frequently play with it in order to give a ghastly appearance to the surrounding

company. When baryt (ponderous earth) is mixed with spirit of wine, its flame is yellow; boracic acid renders it green, and strontian earth gives it a purple colour.

The phenomena of coloured bodies, as they occur to us, in general, may be distinguished into five classes, *viz.* 1st. The colours that arise from evident refraction, such as the colours of the rainbow, of the bubbles of a solution of soap, &c. 2dly. Those of opaque bodies that are fixed. 3dly. The colours of transparent bodies formed by the light passing through them. 4thly. The colours that are changeable, according to the situation of the eye, like the colours of certain silks, feathers, flowers, thin laminæ, &c.; and 5thly. Those which are changeable in consequence of a chemical alteration of the nature of the body. We shall now add a few observations respecting each of those five classes.

1. That in passing through a transparent medium, like the drops of rains, the thin pellicle of a bubble of soap, a thin lamina of talc, &c. the light should be decomposed or rather resolved into colours, is easily understood, after the above-mentioned properties of the prismatic spectrum; but the only circumstance which may require explanation is, that we perceive the colours, &c. not when the refracting body is between us and the luminous object, but when both our eyes and the luminous object are on the same side. With respect to this, it must be observed, that a transparent body, like a plate of glass, a drop of water, &c. reflects with both its surfaces at the same time that it lets part of the light pass quite through its substance. Direct your eyes to the surface of a common glass plate so as to see the reflection of an object, as in a looking glass, and if you observe attentively you will perceive two reflected images close to each other, *viz.* one from the anterior, and the other from the posterior, surface. In most looking glasses, if you place a lighted candle on one side, and view the reflected image of it from the other side, you will generally see a succession of images of the candle fainter and fainter, in proportion as they recede from the principal image. The reason of this appearance is, that since both surfaces reflect, the image formed by the reflection of the posterior surface is partly transmitted to the eye of the spectator, and partly reflected from the anterior surface to the posterior one, the latter of which is again reflected, and so on. Now, in the case of the drops of rain, when they form the rainbow, the light of the sun falling obliquely on the surface of the drop is refracted and resolved into colours, in which state it proceeds through the drop to its farther surface, from which it is partly reflected to the eyes of the spectator. The same explanation is evidently applicable to the colours of the bubbles of soap, thin transparent laminæ, and the like. See Rainbow.

2. The fixed colours of opaque bodies are in all probability owing to their absorbing some of the coloured parts of white light and reflecting others; their immense variety arising from a mixture of the reflected primitive colours in various number and proportion; but it is impossible to say at present whether that reflection is effected at the very surface, or at some distance from it, either within or without the body; also to what cause the disposition of reflecting certain colours in preference to others may depend upon. Mr. Delaval's experiments seem to indicate that the colour of opaque bodies arises from the light that has passed through a thin layer of transparent coloured particles, and is then reflected by the smooth surface immediately under them.

3. The greatest number of accurate experiments, concerning the colours of transparent bodies, was made by Edward H. Delaval, esq. F.R.S. (See his Paper in the Memoirs of the Lit. and Philos. Society of Manchester, vol. ii.) His experiments were performed with an immense variety of liquors differently tinged by metallic solutions, decoctions, and infusions of flowers, resins, gums, woods, mineral and animal matters. Those liquors he placed in phials of flint glass, of a parallelepiped form, with an oblong cylindrical neck. "I covered," he says, "the bottom, and three of the sides of each of these phials, with a black varnish; the cylindrical neck and the anterior side, except at its edges, were left uncovered."

In order to examine what colour those liquors would exhibit, either by transmitted or by reflected light, he viewed them through the neck of the phials, or looked into the phial through the side which had been left uncovered by the varnish. But with respect to this latter case, he says, "the uncovered side of the phial should not be placed opposite to the window, through which the light is admitted; because in that situation the light would be reflected from the farther side of the phial, and would be transmitted through the coloured liquor; and it is observable that smooth black surfaces reflect light very powerfully. Now, as it is a principal object in the experiment that no light be transmitted through the liquors, this will be accomplished by placing the uncovered side of the phial in such a direction that it may form a right angle with the window."

All the coloured liquors, which Mr. Delaval tried in the above-mentioned manner, appeared tinged with their peculiar colours, when viewed through the necks of the phials; but when he looked on that part of the liquor which filled the body of the phials, he perceived no colour whatever, the whole appearing black; which proves an important fact, namely, that transparent coloured liquors do not yield any colour by reflection, but by transmission only. "If these liquors," he observes, "are spread thin on any white ground, they appear of the same colours which they had exhibited when viewed in the necks of the phials; as the light reflected from the white ground is, in this case, transmitted through the coloured medium. But when they are spread upon a black ground they afford no colour. The black ground, however, should not be a polished body; as the light reflected thereby would be transmitted through the thin medium on its surface, and be tinged by passing through it."

Next to the above, Mr. Delaval relates various other experiments which he made with transparent solids, *viz.* with coloured glasses, which he made on purpose, by tinging the substance of the glass with metallic and other matters, in imitation of real gems. These coloured glasses exhibited phenomena similar to the coloured fluids. "Having," this author says, "formed pieces of such glasses, about two inches thick, I inclosed all their sides with black cloth, except at their farther and anterior surface. Each of these pieces of glass vividly exhibited its colour, when viewed by transmitted light: but when the transmitted light was intercepted, by covering the farther surface, the anterior surface afforded no colour, but appeared black. When plates of transparent coloured glass, somewhat thicker than window glass, are viewed by transmitted light, it is well known that they exhibit their several colours. I intercepted the light, which was transmitted through such coloured plates, by fixing a piece of black cloth contiguous to their farther surface. The plates, thus prepared, when placed in such a direction that they form a right angle with the window, appear perfectly black; which shews that the coloured particles do not reflect any light."

It is hardly necessary to observe that wherever light is transmitted through any coloured transparent body, a greater part of it is lost, than when that body is quite colourless; for by transmitting one sort of coloured rays more copiously, it stops a great part of the oppositely coloured rays.

Besides these transparent coloured bodies which have been just noticed, there is a vast gradation of others between them and those that are perfectly opaque. These, which are called semipellucid, or semitransparent, exhibit a vast variety of phenomena arising from the various proportion of the opaque and the transparent particles which enter in their composition. Thus some appear of the same colour, whether viewed by transmitted, or by reflected light, others exhibit one colour by transmitted and another by reflected light; others again appear of various colours, according to their thickness, &c. See Newton's Opt. l. i. p. ii. prop. x.

4. The last paragraph may, in some measure, tend to illustrate the nature of those coloured silks, feathers, &c. which change their colour according to the angle in which they are viewed, and in which the light falls upon them; other circumstances, however, are concerned in the phenomena of those bodies. Thus the surfaces of some of them are very irregular, in consequence of which they reflect with some of their particles, whilst they absorb most of the light with other particles; hence, when by a lateral view, the former or the latter are placed out of the direction of the eye, the colour of the whole appears different from what it does in another point of view. Certain bodies of this sort may likewise be transparent to a certain small depth, in which case they become visible partly by reflected and partly by refracted (consequently decomposed white) light; hence the eye of the spectator must, according to its situation, see some coloured rays in preference to others. The phenomena of those changeable bodies, meaning with respect to colour according to situation, are far from being clearly understood; it is most probable, however, that in them all, the three principal properties of light are concerned, namely, its reflection, refraction, and inflection.

5. In the practice of various arts, wherein colours are concerned, such as in dyeing, enamelling, painting in oil or water colours, &c. a change in colour of most of the materials is commonly observed, which is evidently produced by the action of the air, the fire, the oil, or other agent to which the colouring materials are exposed, and by which they undergo different degrees of chemical alteration in their nature. This observation, and a desire of investigating the nature of those changes, with a view of improving the practical arts dependant upon them, induced several persons to try a variety of experiments, and Mr. Delaval, the same above-mentioned gentleman, who investigated other branches of the present subject, became one of the greatest labourers in this field of inquiry. Were we acquainted with the nature of those particles in bodies which reflect or refract the coloured rays, and had we a sufficient knowledge of the alterations produced on those particles by the action of different agents or menstrua, be they oils, acids, air, alkalis, &c. a just idea might perhaps be formed of the changes in colour, which must arise from certain combinations; but as the present state of knowledge does not admit the formation of such a theory, the whole must rest upon conjecture, and the practical part must depend upon the result of particular experiments.

Sir Isaac Newton thought, that bodies reflect and refract light, by the same power in different circumstances. Also, that the forces of bodies to reflect and refract light, are very nearly proportional to the densities of the same bodies, excepting that unctuous and sulphureous bodies refract more than others of the same density. In support of this assertion he relates several experiments, the result of which he expresses in a table, wherein the proportion of the sines which measure the refractions of the several bodies, the densities of the bodies estimated by their specific gravity; and their refractive powers in respect of their densities are stated in separate columns. Mr. Delaval conceived that the denser substances ought, by their greater refractive powers, in like circumstances, to reflect the less refrangible rays; and that substances of less density, should reflect rays proportionably more refrangible, and thereby appear of several colours in the order of their density. Agreeably to this supposition he gives instances of natural bodies, which differ from each other in density, though circumstanced alike in other respects, excepting in their colour, which colour follows the order of their density; the densest being red, the next in density orange, the next to that yellow, then green, &c. In support of this hypothesis Mr. Delaval made several experiments with glass tinged by metallic particles, in which the colour of the glass, in a great measure, corresponded to the density, or to the specific gravity, of the metal concerned. But this series of experiments is not extended to that degree, nor is it conducted with that caution, which a confirmation of the hypothesis demanded. Mr. Delaval also instituted similar experiments with coloured liquors, in which he endeavoured to shew, that by an incrassation or an attenuation of their particles, their colours may be changed in one order or in the reverse. His mode of attenuating those liquors was accomplished, as he supposed, by the addition of acids, and that of incrassating, by the addition of alkalies. But however specious this hypothesis may at first sight appear, a strict examination of facts will easily shew the fallacy of it in almost all its parts, and several writers have pointed out some of its defects, but none better than Dr. Bancroft, F.R.S. in his "Experimental Researches, concerning the Philosophy of permanent Colours," vol. i. chap. i. In this excellent work, Dr. B. shews that Mr. Delaval has not noticed the change of nature, as well as of specific gravity, which the metals undergo by their being exposed to different degrees of heat, together with the glass. He also observes, that if, according to Mr. Delaval's hypothesis, the densest bodies are of a red colour, or approximating to it, platina, the heaviest of all known metals, ought to be red; whereas it is white, like tin, and the lightest metals. Also gold, the heaviest metal next to platina, is much farther removed from the red colour than copper, which is much lighter. With respect to Mr. Delaval's experiments on coloured liquors, Dr. Bancroft says, "instead of choosing and employing mechanical means, which alone are suited to produce those effects, and only those effects, he has recourse to mere chemical agents, whose actions in the ways which he supposes must have been almost doubtful, though their powers of producing other, and very different effects from what he supposes, is most certain. Mr. Delaval, however, adopting sir Isaac Newton's supposition, that acids always attenuate, and alkalis always incrassate, prepared what he considered as a dissolving or attenuating liquor; which consisted of water with about $\frac{1}{80}$ part of *aquafortis*: and when he wanted to lessen the dissolving force of this liquor, instead of weakening it by the addition of water (which would certainly have been the most obvious and unexceptionable expedient), he chose to do it, as he says, by adding a small quantity of a solution of pot-

ash, or some other alkaline liquor, and thereby produced a new composition, the effects of which must, in many cases, prove different from those of a mere diminution of the supposed dissolving power of the former liquor. And on the other hand, when he wanted to increase the force of his acid liquor, instead of doing it by a farther addition of *aquafortis* (obviously the most proper expedient), he recurs to an addition of *oil of vitriol*, an acid possessing very different properties, and producing very different effects, on a great variety of substances, and particularly on colouring matters; of which we could easily allege hundreds of instances, but shall content ourselves with only mentioning what is well known, that even the strongest and most concentrated oil of vitriol (used to dissolve indigo for dyeing the Saxon blue, &c.) does not destroy, or even weaken, its blue colour, though a very weak nitrous acid, or aquafortis, will wholly destroy it, and convert the indigo to a dirty brown mass, of no use whatever." For farther observations of Dr. Bancroft on Mr. Delaval's Theory of Colours, we refer our readers to his abovementioned work. But with respect to the practical part of the subject, *viz.* the art of colouring glass, porcelain, &c. or the methods of forming pigments, they are requested to consult the articles, PAINTING, ENAMELLING, DYEING, STAINING, CRAYONS, and PIGMENTS.

COLOUR *of the clouds*, is thus accounted for by sir Isaac Newton. Concluding from a series of experiments, that the transparent parts of bodies, according to their several sizes, reflect rays of one colour, and transmit those of another, he hence observes, that when vapours are first raised, they are divided into parts, too small to cause any reflection at their surfaces, and therefore do not hinder the transparency of the air; but when they begin to coalesce, in order to form drops of rain, and constitute globules of all intermediate sizes, these globules are capable of reflecting some colours, and transmitting others, and thus form clouds of various colours, according to their sizes. Mr. Melville controverts this doctrine, in its application to the red colour of the morning and evening clouds. "Why," he says, "should the particles of the clouds become at that particular time, and never at any other, of such a magnitude as to separate these colours? And why are they rarely, if ever, seen tinctured with blue and green, as well as red, orange, or yellow? Is it not more credible, that the separation of rays is made in passing through the horizontal atmosphere, and that the clouds only reflect and transmit the sun's light, as any half-transparent colourless body would do? For since the atmosphere reflects a greater quantity of blue and violet rays than of the rest, the sun's light transmitted through it ought to incline towards yellow, orange, or red; especially when it passes through a long tract of air: and thus it is found, that the sun's horizontal light is tinctured with a deep orange, and even red; and the colour becomes still deeper after sun-set." Hence he concludes, that the clouds, according to their different altitudes, may assume all the variety of colours at sun-rising and setting, by barely reflecting the sun's incident light as they receive it. Edinb. Ess. vol. ii. p. 75. Priestley's Hist. of Vision, p. 446, &c.

For the distinct properties, &c. of the several colours, see BLACK, WHITE, BLUE, &c. See also RAINBOW, &c.

COLOUR, and COLOUR-*Making*, in *Calico-Printing*. The preparation of colours for calico-printing, constitutes one great branch of that beautiful art, and involves in it a series of interesting and important processes. As an art, its operations are more dependent than almost any other, on those minute differences and changes in the constitution of bodies, which it is the business of chemistry to investigate. Hence that liability to error and uncertainty which, in the hands of the ignorant, pervades many of its processes, though conducted according to long established and approved formulæ. Our present volume would scarce suffice for the various receipts in which the art abounds; yet, in the following article, we shall endeavour to lay down general principles, rather than more practical directions; convinced, that by presenting our readers with a clear and concise theory, deduced from such practical illustrations, as may be necessary for this purpose, we shall render them a more acceptable service.

The term *cola*, in calico printing, is applied not only to those vegetable, animal, and mineral solutions, which impart their own colour to the cloth on which they are applied, but also improperly to those earthy or metallic solutions, which, possessing little or no tingent properties themselves, yet retain or fix the colours of other substances, when afterwards applied to the cloth. Thus the acetite of alumine, or printers' red liquor, when pure, is almost colourless, and only becomes red by the process of dyeing, as will be explained hereafter. The acetite of iron, or iron liquor, in like manner, when used of a determinate strength, is called *black colour*, and when weaker *purple colour*, though the cloth impregnated with these solutions becomes black or purple, only as being raised, like the other, in the dye-copper.

1. The colours produced by means of these earthy or metallic solutions (which, in the language of science, are called *mordants*), form the most valuable and important series, whether considered with regard to the almost infinite variety of shades, or to their solidity and durability. These colours, from the mode in which they are produced, (the mordant being first applied to the cloth, and the colour afterwards raised by dyeing), are called *dyed colours*.

2. Sometimes the mordant is previously mixed with a solution of colouring matter, and in that state applied to the cloth, so as to paint or stain it, at one operation, and without the process of dyeing. Thus, another class of colours is produced, many of them possessing great brilliancy indeed, but much inferior to the former in durability. The colours called chemical, by calico printers, belong chiefly to this class.

3. In the third and last class, we may place all those, where the colouring matter is simply held in solution by an acid or alkali, and in this state applied to the cloth, without the intervention of any mordant. To one or other of the foregoing classes, may be referred all the colours used in calico printing; with the exception, however, of those systems of colours which have been produced by calico printers in this country, within a short period, by processes, and upon principles which have hitherto not been made known.

Class I.

The colours of this, as has been already observed, are produced, by first impregnating the cloth with an earthy or metallic solution, or mordant, and raising the colour afterwards by dyeing. In this article we shall confine ourselves to the preparation of the different mordants, and the enumeration of colours they afford, with different colouring substances. The operations of the dye-house, and the mode of raising the colours in the dye-copper, will be detailed hereafter.

The two great and most important mordants used in calico printing, are those that we have already noticed, *viz.* the solution of iron in acetous acid or vinegar, called iron liquor, and the acetous solution of alumine, or the earth of alum, called red liquor, or red colour, and sometimes yellow liquor.

With these two solutions, either separately applied, and

of various ſtrengths, or mixed together, and in various proportions, an infinite variety of ſhades of colour are produced. Almoſt all the hues in nature may be obtained by raiſing them, and their various combinations with different colouring ſubſtances. From madder, with the acetite of alumine, or red liquor, we obtain various ſhades of red, from the darkeſt blood colour to a pink. From weld and quercitron bark, yellows, varying in intenſity from a deep orange to a pale ſtraw colour, according to the ſtrength of the mordant employed. From logwood, various ſhades of violet; from cochineal, Brazil, and Hicaragua wood, pink and crimſons of different hues; and, in ſhort, from almoſt every different colouring ſubſtance, a different ſhade of colour. With the acetate of iron, or iron liquor, of different ſtrengths, we obtain from madder all the intermediate hues between black and pale purple, or lilac. From weld and bark, olives, browns, and drabs, of various hues; from ſumac, logwood, galls, and other aſtringent ſubſtances, all the varieties of grey, from the paleſt ſhades to the deepeſt, in which all the minute differences of hue are loſt till they approach to black. Theſe various ſhades are further modified by applying two or more colouring ſubſtances to the ſame mordant, as madder and weld, for example, to the acetite of alumine, which produces orange, light cinnamon, nankeen, &c.; and again ſtill further, by mixing the mordants themſelves in various proportions, and raiſing them with either one or more of the different colouring matters. By theſe means ſhades, and varieties of colour, may be produced from a few ſubſtances only, which baffle deſcription, and for which language has no preciſe or definite terms.

The acetite of iron, or iron liquor, is variouſly prepared. In this country it is chiefly made with the pyroligneous acid, which Fourcroy has proved to be identical with the acetous. Malt acid is preferred by many on account of its being free from volatile oil and reſinous matter, with which the other abounds; but the great difference in price; and the facility with which it is obtained, has brought the acid of wood almoſt into general uſe. A ſeries of caſks filled with ſcraps and turnings of iron upon which the acid is poured, is almoſt the only apparatus neceſſary for making iron-liquor; yet when the conſumption is great, or when it is prepared for ſale, vats capable of holding ſeveral hundred gallons are ſubſtituted for caſks, and the acid is kept in a ſtate of circulation through the iron by means of pumps. The ſaturation is much accelerated by this motion, which prevents any depoſition on the ſurface of the iron which might defend it from the action of the acid, and alſo brings freſh portions of unſaturated acid more frequently in contact with the metal. In a few weeks, ſooner or later in proportion to the ſtrength of the acid, the ſaturation is completed, and the liquor is then removed from the vat into caſks for uſe, and freſh acid poured upon the iron as before. This is an eaſy and ſimple mode of making iron liquor, and as it requires but little trouble and attention, is the one moſt generally in uſe. The precautions neceſſary to be obſerved are, that the acid, if it be the pyroligneous, ſhould not be uſed too ſoon after its preparation. It holds much eſſential oil and reſin in ſolution, part of which ſeparates on being kept a few weeks, and the clear acid may then be drawn off. It may be ſtill further freed from reſin by boiling; a portion of eſſential oil is thus thrown off, and the reſin, if held ſuſpended, is precipitated after ſtanding ſome time. We ſhall have occaſion to recur to this ſubject again, when we come to treat of the pyroligneous acid, and its formation, under the article *Diſtillation of* Wood. It is neceſſary alſo, that the iron ſhould be perfectly clean and all of it malleable. Caſt iron is not ſoluble in acetous acid. Hoop iron cut into lengths of from eight to ten inches is preferable to any other. It is readily cleaned and more eaſily taken out of the vat, and returned into it again than miſhapen maſſes ſold under the name of old iron. When malt acid is employed, ſimple heating and waſhing is ſufficient to free it from any foulneſs it may have contracted in the vat; but when the pyroligneous acid has been uſed, it becomes ſo coated with reſin on its upper ſurface after a ſecond or third ſolution, as to prolong the period of ſaturation to twice or thrice its uſual length. In this ſtate it muſt be removed from the vat and heated to redneſs in oven, through which there is a current of air. The reſin is conſumed, and the iron by heating is freed from any remains of carbonaceous matter that may adhere to it, and is again ready for the vat.

The only objection to this mode of making iron liquor is the time required to ſaturate the acid, which to thoſe, whoſe conſumption is very great, or who manufacture it for ſale, is oftentimes of importance. Different proceſſes have therefore been deviſed to remedy this inconvenience, in many of which the ſaturation is accelerated by means of heat which is applied in various ways, as beſt ſuits the convenience of the manufacturer; but the moſt expeditious mode is that of preſenting the iron to the acid in a ſtate of oxydation, by which means the ſolution is effected immediately. Calico printers have long been in the habit of uſing an extemporaneous acetite of iron, formed by mixing together ſolutions of acetite of lead and ſulphate of iron. A very pure acetite of iron may be obtained by this means, but the price of acetite of lead renders this mode too expenſive for general uſe. By forming a ſolution of lead, however, in pyroligneous acid and decompoſing it with ſulphate of iron or copperas, an iron liquor may be obtained ſufficiently cheap to render this proceſs advantageous in many caſes, though ſtill more expenſive than the ordinary mode. A patent was lately taken out for making iron liquor by a proceſs ſomewhat ſimilar to this, which, however, we underſtand has not anſwered the expectation formed of it. A ſolution of lead in pyroligneous acid is digeſted on clear metallic iron. The iron becomes oxydated at the expence of the lead and is diſſolved, whilſt the lead is precipitated in the metallic ſtate, and may again be uſed for a freſh ſolution. All theſe modes are evidently more expenſive than the ordinary one of ſimple ſolution of metallic iron in pyroligneous acid, and the only conſideration with the manufacturer is, whether this extra expence is counterbalanced by the economy of time or not.

The proceſs adopted ſome years ago by Mr. Thomſon, is perhaps the moſt expeditious, and, next to the common mode, the moſt economical of any yet in uſe. It conſiſts in ſaturating the pyroligneous acid with quicklime, and pouring the clear boiling ſolution on as much ſulphate of iron or copperas as will precipitate the whole of the lime. A caſk of iron liquor may be made by this mode in a few hours, and when care has been taken rightly to proportion the ingredients ſo as to produce complete decompoſition, it is inferior to no ſolution whatever in any of its properties.

The properties of the acetous ſolution of iron fit it eminently above all others for the purpoſe of the calico printer, and having detailed its preparation we ſhall endeavour to point out in what this ſuperiority conſiſts.

The acetite of iron exiſts in two ſtates, dependent on the quantity of oxygen combined with the iron. When pure, and recently prepared, it is of a pale greeniſh hue, but by expoſure to air ſoon becomes tinged with brown. In this ſtate the iron is at its loweſt point of oxydation, ſtrongly attractive of oxygen, and if precipitated by an alkali, of a deep green colour. By expoſure to the atmoſphere, and conſe-

quent abſorption of air, the ſolution paſſes to a deep red brown, and, if concentrated, depoſits orange oxyd of iron, and becomes ſtrongly acidulous. With this exceſs of acid, the ſolution now becomes permanent; the iron is almoſt wholly at the maximum of oxydation; and, when precipitated, of a dark red colour.

The ſame takes place only in a leſs degree, and more ſlowly with the ſulphuric and muriatic ſolutions of iron. Of a pale greeniſh hue in their recent ſtate, they gradually attract oxygen from the atmoſphere, and become ſlightly red, depoſit red oxyd of iron and paſs to a ſtate of acidity, at which the ſolution becomes permanent, and the oxydation of the iron proceeds no further.

If the ſolutions, properly thickened with gum or flour, are applied to cloth, the ſame change takes place, but with more rapidity, from their diffuſion over a thin ſurface, and more complete expoſure to the air. The aqueous and volatile part of the ſolution ſpeedily evaporates, and as the oxydation goes on, the oxyd of iron is depoſited on the cloth, and a portion of acid ſet free. When this acid is volatile, as is the caſe with the acetous, and alſo in a great degree with the muriatic, it is diſſipated. The oxydation of the iron then goes on, freſh portions of acid are again liberated and drawn off till the whole of the ſolution is decompoſed, and the oxyd of iron depoſited in the cloth. When the acid is not volatile, however, as is the caſe with the ſulphuric, the firſt portions of acid that are liberated not being drawn off, the oxydation proceeds more ſlowly till the exceſs of acid becomes ſo great as wholly to interrupt it, and great part of the iron in the operation of rinſing is again carried off the cloth. Another and more ſerious inconvenience attending the uſe of the ſulphuric ſolution is its action on the cloth itſelf. The diſengaged acid being in a ſtate of great concentration acts upon its fibres, weakens, and at laſt deſtroys them. The ſame takes place with the muriatic ſolution alſo, for though the exceſs of acid is ſlowly diſſipated, yet it has ſufficient time and concentration to act very powerfully, and is, if poſſible, ſtill more deſtructive than the ſulphuric, ſince its action is not confined to the part on which it is applied, but from its volatility extends over the whole ſurface of the cloth.

It is neceſſary, therefore, that the acid ſhould be not only volatile, but harmleſs in its action on the vegetable fibre, which conditions are more completely fulfilled by the acetous than by any other ſolution whatever. From the preceding obſervations on the properties of the acetite of iron, and the changes it undergoes on the ſurface of the cloth, may readily be deduced the reaſons for that expoſure to heat and air which calico printers have, from long experience, found neceſſary to goods printed with this ſolution. By expoſure to air the iron becomes oxygenated and depoſited on the cloth, whilſt the heat favours the liberation of the acid, and accelerates the proceſs. From what has gone before it may alſo be inferred, that the acetite of iron ſhould be uſed in its recent or *green* ſtate, ſince in that ſtate the acetous acid is capable of holding a greater quantity of oxyd of iron in ſolution, and that conſequently after its ſaturation and removal from the iron, it ſhould not be too much expoſed or agitated in contact with the air. On this account, alſo, it is wrong to pump the liquor in the vats too much when it approaches the point of ſaturation, ſince the oxygenated iron is almoſt all precipitated, and freſh portions immediately diſſolved, ſo that the liquor might in time be rendered quite thick with precipitated oxyd of iron.

The preceding ideas are at variance with the general opinion reſpecting the ſtate in which the acetite of iron ſhould be employed. All the ſpeculative writers, and even many well acquainted with the proceſſes of calico printing, recommend the oxygenation of the ſolution by expoſure to air and removal from the iron, as eſſential to the goodneſs of the iron liquor. Even Berthollet, in the laſt edition of his "Elements of the Art of Dyeing," has fallen into the ſame miſtake, the ſource of which, and the facts which ſeem to countenance it, we ſhall point out in a future article.

It is an object of importance to the calico printer to know the preciſe ſtrength of his iron liquor, and to be able to aſcertain this at all times, with little trouble or chance of error. Great miſchief and inconvenience often ariſes from uncertainty in this reſpect, eſpecially in the pale ſhades of purple, which are obtained from madder, with diluted acetite of iron. The hydrometer has been objected to, as indicating not merely the quantity of iron in a ſolution, but alſo the eſſential oil, reſin, and mucilage which theſe impure ſolutions often contain. This objection, however, only applies where the ſame inſtrument and graduation is employed to aſcertain the relative ſtrengths of iron liquors, prepared with different acids, as the pyroligneous which contains much eſſential oil and reſin, and malt acid which abounds in mucilage. In this caſe the hydrometer may indicate great differences in ſolutions containing equal quantities of acid and iron, but varying in the quantities of mucilage, oil, or reſin. Iron liquor, however, prepared conſtantly by the ſame proceſs, and from the ſame acid, varies ſo little in the relative proportion of its ingredients, that the hydrometer may be uſed to aſcertain its ſtrength in preference to any other mode whatever; provided the neceſſary precautions are uſed to correct any error ariſing from variation of temperature.

In a work of this kind, not illuſtrated by actual ſpecimens, and without reference to ſome particular kind of iron liquor, it is impoſſible to point out the ſpecific gravities of the different ſolutions required for producing the various ſhades, we have enumerated. An acetite of iron, of ſpecific gravity 1.047, with madder or logwood, will produce a black, and with weld or ſumac an olive, and diluted with ſix, eight, or ten times its bulk of water, various ſhades of purple, drabs, or olives, according to the colouring matter employed. A ſtandard ſolution of iron once obtained, the neceſſary ſtrength for producing the different varieties of colour is eaſily aſcertained by actual experiment, and to this we muſt refer our readers.

When thickened with flour or gum, and tinged with a decoction of logwood or Brazil, the better to enable the workman to obſerve the progreſs and ſtate of his work, it forms, as we have before obſerved, the printers black colour, a purple colour, &c. according to the ſtrength of the ſolution and the purpoſe it is intended for. Various ingredients were formerly added to iron liquor, to improve its quality, or vary the hue of colour it produced. Verdigriſe and copperas were added to the ſolution intended for black; and ſal ammoniac or nitre to the diluted ſolutions for purple. Theſe are, however, now almoſt univerſally laid aſide, as being for the moſt part uſeleſs, and often hurtful: the ſimple acetite of iron being found to anſwer every purpoſe of the more complicated and heterogeneous ſolutions.

The *acetite of alumine*, or red liquor, is always prepared by the decompoſition of alum, by an earthy or metallic ſalt, ſince the aluminous earth is not ſoluble in acetous acid, except in its newly precipitated and minutely divided ſtate. The pureſt ſolution, and that which is generally uſed for the fineſt and moſt delicate colours, is produced by decompoſing alum with Dutch ſugar of lead, generally in the proportion of two parts by weight of the former, to one of the latter. The proportion of the two ſalts, and alſo the quantities of each gallon, as uſed by different calico printers, vary yet

with little difference in effect. The alum in general predominates so far as completely to saturate the liquor. The printers' aluminous mordant therefore is a compound solution. It is an aceto-sulphate of alumine, consisting of a saturated solution of common alum, and more or less acetite of alumine, according to the quantity of sugar of lead employed. In the neighbourhood of London, the proportions are 6lb. of alum, and 3lb. of sugar of lead to a gallon of water: when these are completely dissolved, one ounce of Spanish white is added, and the whole briskly stirred till the effervescence has in great measure subsided. In a few hours the solution becomes clear, and forms a standard liquor from which, by greater or less dilution, may be obtained all the various shades of red, yellow, &c. already enumerated. In the above formula the proportion of alum is somewhat too great, a part of it remains undissolved, or immediately recrystallizes, and falls to the bottom along with the precipitated lead. This excess of alum is however strongly insisted on by many calico printers, as essential to the purity of the mordant, from an idea that the *purest* part of the alum only is taken up in the solution. This fact however may be readily disproved by employing this undissolved or recrystallized alum in the formation of fresh solutions, whose purity will be found in no respect inferior to the former. The purity of the alum and sugar of lead, and especially their being free from iron, is of great importance in the preparation of this mordant, and on this account the Dutch sugar of lead is preferred; but its high price renders it too expensive except for the pale reds of light chintz, and other kinds of work, whose great delicacy in the red tints is required. A substitute for it has been found in the solution of litharge in vinegar, or pyroligneous acid, which is afterwards decomposed by the addition of alum, and the excess of acid neutralized by Spanish white as in the former case. Great part of the acetite of alumine manufactured and sold under the name of red liquor is prepared in this manner. It is in general used for yellows, dark shades of red, and for those compound mordants into which the acetite of iron enters, and when its purity is of course of little consequence. The acetite of lime has long been substituted with great advantage by the writer of this article for the solution of lead, and its use is becoming daily more known and extended. When carefully prepared, it is scarce inferior to the best sugar of lead, and the impure solutions answer equally with the best, for the compound mordants before mentioned. The theory of these processes is the same in all. The object being to obtain a solution of alumine or earth of alum in acetous acid. On mixing acetite of lead, and sulphate of alumine together, a change of bases takes place; the sulphuric acid unites with the lead, and falls down in the form of a white heavy precipitate, whilst the earth of alum combines with the acetous acid, and remains in solution. The same takes place with the solution of litharge in pyroligneous acid, which is indeed an impure acetite of lead, and when the acetite of lime is employed instead of lead, the sulphuric acid and lime unite and form an insoluble powder, which subsides, though less quickly than the other, whilst the acetite of alumine remains in solution above; the addition of the Spanish white is necessary to saturate a small excess of acid which exists in the solution. This excess is taken up by the lime, and immediately converted into acetite of alumine, by the decomposition of a fresh portion of alum.

The acetite of alumine when pure, is almost colourless. It has a slight acetous smell, and when boiling throws off acetous acid in great abundance, and deposits a portion of alumine. When evaporated it acquires a thick gummy consistence, but does not crystallize a property which gives it a decided advantage over common alum as a mordant. It unites readily with gum, but when concentrated and holding much alum in solution, forms with flour a watery pulpy kind of paste, which has little adhesion, and from which the fluid soon separates. The sulphuric salts have indeed all a disposition to injure the thickening quality of flour.

The affinity of cotton for the earth of alum, is so strong as to separate it from its combinations even with the mineral acids. When a solution of common alum properly thickened is applied to cloth, a portion of alumine unites with it, and the acid, which held it in solution, is set free. When this is accumulated to a certain degree, it prevents any further decomposition, and in rinsing carries off the greater part of the earth again. When the acid however is volatile, like the acetous, and is dissipated as soon as disengaged, there being no longer any obstacle, the decomposition goes on till the whole of the acid is driven off, and the alumine combined with the cloth. In the infancy of calico printing, and before the theory and constitution of the different mordants was properly understood, a variety of substances were added to the solution, some of which are retained to this day. Verdigrise in the proportion of two ounces to a gallon, is recommended by many as tending to exalt the hue of yellows, and may in some cases be useful. Corrosive sublimate has been but lately laid aside, and the nitro-muriate of tin was long thought to give fixity and brillancy to reds, when used in a small proportion with the aluminous mordant. In general, however, the aceto-sulphate of alumine is found adequate to every purpose of the calico printer; we shall not, therefore, perpetuate error by detailing any of those unmeaning mixtures which are still retained by the ignorant and prejudiced. These two mordants, the acetites of iron and alumine, and their various combinations, are those only in general use in calico-printing, for producing colour of the first class. This application is so extensive, and at the same time so simple, as to supersede the necessity of any other. The solutions of copper are sometimes used as mordants, but they afford colours of little solidity. The solutions of tin have also been employed, but we shall speak of these and other earthy and metallic solutions which have been used with partial success, when we come to treat of mordants in general.

Class II.

In this class the colours are produced by combining a solution of colouring matter with some earthy or metallic salt, capable of giving it fixity when applied to the cloth. The mordant and colouring matter are here applied at once, and the cloth is painted, as it were, or stained, with the colour it is intended to retain, and requires, in general, no farther operation than that of rinsing, to free it from the paste or gum with which it was thickened.

The colour of this class possesses, as we have before observed, in general great brilliancy, but wants that solidity and fixity which characterise the colours of the former class. The union of the mordant with the cloth is weakened by its previous combination with the colouring matter, and not being favoured by heat, as in the former case; the triple combination of vegetable fibre, mordant, and colouring matter, wants that solidity which is so necessary to constitute what is called a fast colour.

Many of these, however, are sufficiently durable to be partially introduced, and intermixed with other colours of greater durability, and some are indispensably necessary, as no better mode has yet been devised of producing them. When the

chemist's art shall have discovered means of giving fixity to colours thus topically applied, the art of calico printing will have arrived at perfection. Systems of colours may then be combined, which are at present incompatible, and the tedious operation of dyeing and bleaching, with their attendant difficulties, be banished from the art. Nor is the hope so chimerical as might at first be imagined; several of the most useful and permanent colours are of this description, as will be shewn hereafter.

We shall content ourselves with describing the leading and most useful colours of this class, giving, at the same time, the theory of their constitution. The mere enumeration of all the varieties that have or may be formed, would be endless, and foreign to our purpose.

Chemical Black.

This is the most useful colour of the class, and one of indispensible necessity in certain combinations of colours, where, for instance, it is mixed with drab, olive, and yellow, raised in the dye-copper with weld quercitron bark, or any similar colouring matter, and where the presence of any substance, such as logwood or madder, capable of producing a full black, would be ruinous to the other colours. A deep olive, approaching to black, might, indeed, be produced, by employing a strong iron liquor, as mordant, and using sumac in the dye-copper; yet as this would bear no comparison in point of intensity with the madder or logwood black, and as the force of the colouring in such course of work greatly depends on contrast, the topical or chemical black, which has all the intensity required, is almost constantly employed. The constitution of this black is pretty nearly the same in all the different formulæ in use. It consists always of a solution of iron combined with a solution of colouring matter generally of an astringent nature. On the right proportion of these two solutions, and on their due specific gravity or strength depends, in a great measure, the goodness of the black.

1. If to a decoction of Aleppo galls, in five times their weight of water, made into a paste with flour, a solution of iron in nitrous acid of specific gravity 1.25 be added, in the proportion of one measure of nitrate of iron to eighteen or twenty of the former, a black will be formed fit for almost all the purposes of calico printing, and possessing the chief requisites of this colour, namely, tolerable fixity, and a disposition to work well with the black.

2. In lieu of nitrate of iron, some calico printers employ copperas, in the proportion of one pound to a gallon of the decoction of galls. Half the copperas is directed to be dissolved in the gall-liquor before it is thickened with flour; the remaining half, dissolved by heat in as much aquafortis as will cover it, is added afterwards. This black has tolerable fixity, but does not work so well as the preceding.

3. Copperas dissolved in various proportions of from four to twelve ounces per gallon, will form, with decoction of galls or logwood, blacks of less solidity indeed than the former, yet applicable, nevertheless, in many cases where the others are not.

The constitution of the two last-mentioned blacks differs somewhat from the first. We shall point out this difference, and explain, as concisely as possible, the rationale of the foregoing processes.

When a solution of iron in nitrous acid is added to a decoction of galls, as in the first example, the solution is decomposed, the iron unites with the gallic acid and tanning principle, whilst the nitrous acid is disengaged. This is proved by the blackness which the solutions assume immediately on being mixed. The disengaged acid, however, shortly re-acts on the new compound, the blackness gradually disappears, and in a few days, if the nitrate of iron has been added in proper quantity, the paste, instead of black, is of a dirty olive green. If the proportion of nitrate of iron be greater than $\frac{1}{18}$, this change will be effected sooner; and if so high as $\frac{1}{10}$, the paste, when applied to the cloth, will be a bright orange, like the acetite of iron. By exposure to heat and air, this colour generally deepens, becomes grey, and at last a full black. In this state it is permanent, and adheres powerfully to the cloth. These changes of colour depend on the solution of the tannate and gallate of iron in the disengaged nitrous acid, and the evaporation of the acid when exposed to heat and air on the cloth. This solution of the tannate and gallate of iron is indeed an essential requisite in the goodness of the chemical black. If the disengaged acid is not sufficient to effect this, or if it is in too great a state of dilution, the colour has but a feeble adherence to the cloth; it is not presented in a state favourable to its union with it, since the combination into which the iron has entered is insoluble in water. It lies merely on the surface, but does not penetrate its fibres, and yields readily in the various operations to which it is subjected. The chemical black, therefore, of the first example is a solution of the tannate and gallate of iron in nitrous acid.

The black of the second, but more particularly of the third example, differs from the preceding in the circumstance of the iron in the solution being in a less oxygenated state. We may consider this black in its recent state as a mixed solution of green sulphate of iron, and gallic acid, and tanning principle; for the decomposition of the sulphate is not complete till by exposure to air on the cloth the iron becomes fully oxygenated. When this black is recently applied to the cloth, it is of a pale greyish colour, has little fixity, simple rinsing in cold water being sufficient to fetch nearly the whole away. By gradually absorbing oxygen, it becomes deeper, and at last black. The sulphuric acid has no longer any action on it, and is removed in the first operation in which it is immersed in water.

The decoction of galls used for chemical black is variously prepared. Many calico printers infuse the galls cold in casks of vinegar, or pyroligneous acid, suffering them to remain several months, occasionally drawing off the lower part, and returning it on the galls. Others steep them in urine. Both these modes are vicious, particularly the last. Simple boiling in water, till all the soluble matter is extracted is sufficient, taking care to inclose the galls in a sack, that when soft they may not render the decoction thick.

Grey.

By diluting the chemical black of the first example with once, twice, thrice, &c. its bulk of water, and thickening the solution with gum, various shades of grey are obtained, which require rinsing off in water only, and the deeper shades of which have tolerable permanence.

The theory of these mixtures is the same as of the black, from whence they are derived. On the addition of water to the olive-green solution, mentioned in the preceding article, the colour instantly becomes deep purple, approaching to black. This is occasioned by the dilution of the free acid, which being no longer able to hold the tannate and gallate of iron in solution, sets part of it at liberty, which instantly regains its colour. For the reason already assigned, this has less adherence to cloth than that in which the solution is more perfect. The addition of a small quantity of nitrous acid effects this. The olive-green colour of the solution is restored,

which, by exposure to the air, and consequent evaporation of the acid, disappears, and leaves the tannate and gallate of iron more firmly fixed on the cloth. The complete precipitation of the combination is afterwards effected in the operation of rinsing off in water.

Yellow.

The false or chemical yellows are generally prepared with decoctions of French or Turkey berries, and sometimes with quercitron bark. The latter substance produces pale yellows or straw colour, but does not afford the deep bright orange yellow of the berries. Dr. Bancroft, to whom the public is indebted for the introduction and knowledge of this most useful dyeing drug; indeed, asserts the contrary in his work on "Permanent Colours;" and has given a receipt for the bark-yellow, which has, however, never succeeded in our hands.

Berry-yellow. Boil two pounds of good berries, slightly bruised, in a gallon of water during three hours, taking care to replace, from time to time, the evaporated water with liquor obtained from the second boiling of a former quantity of berries. When the liquor is cool, add to it eight ounces of alum, and if it is intended for the block thicken it with flour. If it is meant for those small objects in printed goods, which are generally touched with the pencil, two ounces of sugar of lead should be added with the alum, and the colour thickened with gum dragon. This yellow is generally passed through lime water as the first part of the operation of rinsing; by this means the greater part of the earth of alum, which would otherwise have been carried off in the operation, is precipitated on the cloth, and the colour considerably heightened.

When this operation of liming cannot be performed without injury to some other colour, a greater proportion of sugar of lead should be added. This decomposes the alum, and forms an acetite of alumine, which being more readily decomposed by the colouring matter and the cotton than sulphate of alumine, does not require the assistance of an alkaline solution to precipitate it on the cloth.

The proportion of berries above directed is for a full yellow; one fourth or one-third less will form, with the same quantities of salts, yellows of great brightness. Some calico printers add a small quantity of nitrate of copper to the yellows intended to be simply rinsed off without liming. This heightens the colour, but what is gained in intensity is lost in brightness; for if the solution of copper be added in sufficient quantity to produce any very perceptible effort, it imparts a dulness to the hue which is very detrimental. This is the invariable effect of copper in any shape, whether the acetite, sulphate, or nitrate of copper be employed.

Bark yellow. For a lemon or straw colour, it will be sufficient to make a decoction of bark by boiling from four to six pounds in as much water as is necessary during two hours, and after evaporating down the decoction to one gallon, add to it two ounces of sugar of lead, and eight ounces of alum. If not limed, the proportion of sugar of lead should be doubled. For strong yellows, Dr. Bancroft directs the addition of both nitrate of copper and nitrate of lime in quantities so great, as near seven ounces of the former to a gallon of colour. Experience, however, though it has done justice to the merits of Dr. Bancroft's discovery of the use of quercitron bark, has not verified the expectations he had formed of it as a substitute for the Turkey berries in the topical or chemical yellow.

The constitution of these colours, whether formed with the sulphate and acetite of alumine, or with the solutions of copper is the same. Alumine, or the earth of alum, and the oxyd of copper, have an affinity both for colouring matter and vegetable fibre. They form the connecting link between these substances, which would otherwise counteract a feeble union. When a solution of alum is added to a decoction of berries or of bark, a slight precipitation takes place by the union of a portion of colouring matter with the earth; the greater part however remains suspended or held in solution by the acid of the alum. When applied to the cloth the farther decomposition of the salt is aided by the affinity of this substance for alumine, and, when the acid is volatile, as the acetous for example, by its consequent evaporation. The same takes place with the solutions of copper. The operation of rinsing farther aids the precipitation of the colouring matter and alumine, by thus largely diluting with water; and lastly, when the goods are previously passed through the lime tube, the decomposition is complete, the last portions of earth or oxyd are precipitated, and the colour thereby considerably exalted.

The solutions of tin are capable of forming very bright and beautiful yellows, with decoctions of different yellow colouring substances; but the excess of acid which these solutions necessarily contain, and their powerful action on the cloth, renders their application less general than the preceding. The solution of tin most proper for yellows is the muriatic, and is formed by digesting, in a low heat for several days, the common muriatic acid, or spirits of salt, on fine grain tin. This solution forms, with bark, a pale and lively yellow, and with berries a yellow bordering more on orange. These spirit yellows, however, as they are improperly called, are seldom used except upon dyed grounds, and of this preparation for such purposes we shall treat at large under the head of *Discharged* WORK.

Blue.

The only blue belonging to this class is that produced by combining the colouring matter of logwood with the oxyd of copper. It is but seldom used since the mode of dipping China blue has become generally known; and indeed its want of durability renders it of little value. It may be produced by combining almost any of the solutions of copper with a decoction of logwood.

1. Boil two pounds of logwood in a gallon of water, and to the decoction, thickened with gum, add eight ounces of sulphate of copper.

2. To a decoction of logwood as above, add two ounces of sulphate of copper, and two ounces of verdigrise.

Their colours may either be rinsed off or limed, as best suits the style of work. The theory of these combinations is the same as the preceding.

Green.

The chemical or false green is a compound colour, and consists of a mixed decoction of logwood and berries, or bark, and a solution of copper. Though fugitive, its use is in some degree authorized by the impossibility of obtaining a green of greater durability that can be applied in figures with the block. The fast green of the calico printers is the product of two operations, and is of course limited in its application, and tedious in its use. The production of a fast green at one operation, or rather by one application to the cloth, either with the pencil, block, or press, is one of the great *desiderata* of calico printing.

1. One pound of logwood and two pound of berries boiled together during two hours, and strained whilst hot

upon two ounces of fulphate of copper, and two ounces of verdigrife, and thickened with gum, form a good and lively green, the hue of which may be varied at pleafure by the increafe or diminution of the proportion of logwood. To this fome calico printers add two ounces of common falt, and two ounces of fal enixon or acidulous fulphate of potafh.

2. To one meafure of blue of the firft example in the preceding article, add two, three, four, &c. meafures of a decoction of bark, made by boiling fix pounds as before directed for the yellow, and to which, when reduced to one gallon, two ounces of fulphate of copper, and two ounces of verdigrife have been added. The tone of the green depending on the relative proportions of blue and yellow, it is, in general, beft to keep the two decoctions feparate, to be mixed, when wanted, in fuch proportions as may beft fuit the purpofe required. The theory of thefe mixtures is the fame as of the blue and yellow already defcribed. To the eye of the mere fpeculative chemift, the addition of common falt and acidulous fulphate of potafh in the firft example, may appear unneceffary and unmeaning. They indeed affect little, either the hue or fixity of the colour, but experience has proved that this addition facilitates its working with the block, more efpecially when thickened with gum dragon. The caufe of this, in the particular inftance before us, is perhaps not very clear. The fulphuric falts in general, fuch as the fulphates of alumine, iron, and copper, are all unfavourable to working, as their folutions, efpecially when concentrated, neither thicken well with flour nor gum. A faturated folution of copperas cannot be thickened with flour, nor can a ftrong folution of the aceto-fulphate of alumine, in which the alum is in great excefs; even with gum it unites with difficulty. But if to a folution of copperas, which refufes to form a pafte with flour, a fmall portion of nitrate of iron be added, the whole forms a good and fubftantial pafte that works admirably with the block; and half a pound of common falt added to the aceto-fulphate of alumine has a fimilar effect. In the inftance more particularly before us, the addition of common falt forms a muriate of copper by the decompofition of the fulphate; but this laft is in too fmall a quantity to affect the working of the colour very fenfibly. The caufe of thefe effects is to be fought for in the very complicated play of affinities, which exift in fuch compounds, and which future inveftigation and difcovery may perhaps unfold. The fpeculative philofopher, who is ignorant of the minute details of an art, that involves in it confideration and difficulties, unfufpected in the laboratory, will hence learn to fufpend his judgment in deciding on the merits of a formula, till experience fhall have proved the inutility of thofe ingredients which theory would reject as abfurd.

But to return to our fubject, there is a wide field open for experiment and difcovery in the production of greens, into which logwood does not enter. A calico printer near London, celebrated for his ingenuity and invention in colours of this clafs, has long employed a green which, from its beauty and durability, when compared with the foregoing colours, indicate the prefence of indigo as a conftituent part. Pruffian blue in a minutely divided ftate, and mixed with bark or berry-yellow has been employed; but the blue in this cafe has fo little adherence to the cloth, that mere mechanical force, the operation of rinfing and wafhing is fufficient to difengage it. With one or other of thefe fubftances, however, it is likely that greens much fuperior in beauty, and probably alfo in durability to thofe generally in ufe, might, by a feries of patient and well conducted experiments, be readily obtained.

Pink.

The pale, and more delicate fhades of red, belonging to this clafs, are chiefly fought after in calico printing. They are employed in giving relief or effect to other admixtures of a more fober caft, and all the fkill of the colour-maker is exerted in giving them brilliancy and richnefs of tint. They are chiefly produced from decoctions of Brazil, nicaragua, or peachwood, and cochineal, raifed and fixed on the cloth with folutions of tin, rarely with the aluminous mordants, though delicate and lively colours may be produced this way.

The nitro-muriate of tin is chiefly employed, though the relative proportion of the two acids, and their degree of faturation with tin, varies almoft with every calico printer. The folution itfelf, made according to eftablifhed rule, and with the fame properties, varies fo confiderably at different times, as wholly to alter the nature of its compounds, without any apparent caufe of failure. The fource of this difcordance is to be fought for in the conftitution of the folution itfelf, which, from caufes that we fhall endeavour to explain, is fubject to confiderable variation.

Firft, from the ftrength or concentration of the acids employed, which are feldom uniform or conftant; muriatic acid from the fame manufacturer varying often in fpecific gravity from 1.12 to to 1.18, and nitrous acid not lefs than from 1.15 to 1.23, without reference to the common diftinction of fingle and double aquafortis.

When the fpecific gravity of the acids is neglected, as is but too generally the cafe, thefe differences occafion ferious inconveniences in the ufe of folutions, whofe properties often depend on the accuracy of their proportions, and on determinate degrees of faturation.

Secondly, from the impurity of the acids. The muriatic acid of commerce always contains iron and fulphuric acid; if the former exift in any notable proportion, it is unfit for the folution of tin; the prefence of the latter is of lefs importance, though, on the whole, unfavourable to delicate colours. The nitrous acid varies confiderably in its purity, being fubject to greater or lefs admixture with the muriatic, the nitre it is made from being feldom free from marine falt. The aquafortis of commerce is, in fact, an aqua regia. This variation of the proportion of muriatic acid in the nitrous, is of the utmoft importance, fince the properties of the folution eminently depend upon this. With muriatic acid only, tin forms a colourlefs and permanent folution, one of whofe diftinguifhing properties is, its ftrong affinity or attraction for oxygen. With decoction of cochineal, it forms a deep and dull purple-coloured precipitate, which, however, gradually abforbs oxygen, and becomes crimfon, efpecially when expofed on the filtre. With decoctions of Brazil and peachwood, it affords crimfon precipitates, varying in intenfity with their faturation with tin. It decompofes all the combinations of iron with colouring matter, deoxygenating the iron which it carries off, leaving the tin in combination with the colouring matter. Thus a madder black becomes a red on the application of muriate of tin. On this property is founded the art of printing on dyed grounds, of which we fhall treat hereafter. With nitrous acid, unlefs very dilate, tin contracts a very feeble union, and is generally precipitated as foon as diffolved, in a ftate fully faturated with oxygen. The addition of a fmall quantity of muriatic acid renders this folution more permanent, provided it be not fully faturated with tin, and the addition

of larger portions approximates the solution still more to the nature of the former, and renders it capable of supporting a greater degree of saturation. The properties of the solution depend greatly on the proportion of muriatic acid, and consequently of muriate of tin contained in it. When small, the precipitate with cochineal is bright carmine scarlet. It does not decompose the combinations of iron with colouring matter, unless the solution be far from saturation, and this effect is then due to the disengaged acid only.

The purity of the tin is another requisite which should be carefully attended to. The fine tin of Cornwall, commonly called grain tin, should be employed. If alloyed with lead, it is wholly unfit for these purposes.

In lieu of muriatic acid, sal ammoniac and common salt are oftentimes employed to form an aqua regia with nitrous acid. The solution differs little from that formed by a mixture of the two acids, the allowance being made by the portion neutralized by the alkali of the neutral salt.

From this short outline of the history of the substances employed in the formation of the solutions of tin, and of the properties of the solutions themselves, may be deduced such general ideas as will elucidate and explain many anomalous effects in their combinations with different colouring matters, and seem to direct future experiment in the discovery of those minute, but often important, conditions necessary to the formation of particular shades of colour.

The following examples of spirit reds, as they are improperly called by calico printers, will illustrate some of the preceding observations, and may be considered as specimens of the most beautiful and brilliant colours it is possible to form upon cotton.

1. Prepare an equa regia by dissolving two oz. of sal ammoniac in one pound of nitrous acid of specific gravity 1.25. To this add two ounces of fine grain tin; decant it carefully off the sediment, and dilute it with $\frac{1}{4}$ its weight of pure or distilled water.

To one gallon of water add one pound of cochineal, ground as fine as flour; boil half an hour; then add two ounces of finely pulverized gum dragon, and two ounces of cream of tartar, and stir till the whole is dissolved. When the liquor is cool, add one measure of the preceding solution of tin, to two of the cochineal liquor, and incorporate well by stirring. Apply this with the pencil or block, suffer it to remain in the cloth six or eight hours, then rinse off in spring water. This colour will be a bright and beautiful scarlet.

2. Boil 12 pounds of Brazil chips during an hour in as much water as will cover them. Draw off the decoction, and pour on fresh water, and boil as before. Add the two liquors together, and evaporate slowly down to one gallon. To the decoction whilst warm add four ounces of sal ammoniac, and as much gum dragon or senegal as will thicken it for the work required. When cool, add one of the solution of tin before described, to four, six, or eight of the Brazil liquor, according to the colour wanted. Suffer it to remain from 18 to 24 hours on the cloth, then rinse off in spring water as before. The colour will be a pale and delicate pink. If it is required deeper, the decoction must be made stronger, and used in the proportion of three or four to one of the solution of tin. Nicaragua or peachwood, though not so rich in colouring matter as Brazil, yields a colour, however, which is, if possible, more delicate and beautiful. The fine pinks produced by certain houses, which have, for years been the envy and admiration of the trade, are afforded by this fine dye-wood.

These colours require no liming, simple affusion with water being sufficient to precipitate the colouring matter in combination with the tin. The theory of these mixtures is the same as the preceding. They require, however, a greater excess of acid to hold the colouring matter in solution. A decoction of cochineal poured into a saturated solution of tin, occasions an instant precipitate which is not redissolved, and the greater part of which, if applied to cloth, would come off in the operation of rinsing. It is sometimes necessary to add a small quantity of muriatic acid to prevent this precipitation, or to correct it when it happens, and sal ammoniac is supposed to have the same effect, probably by engaging the water of the solution.

With the aluminous salts, the decoction of cochineal and Brazil forms colours less brilliant than those we have just described, but which are applicable in cases where the excess of acid in the solutions of tin is attended with inconvenience.

1. To one gallon of water, add eight ounces of finely ground cochineal, and two ounces of bruised galls; boil half an hour, strain the liquor whilst hot through a fine cloth, upon four ounces of cream of tartar and four ounces of gum, and thicken with gum dragon. This colour requires liming.

2. Upon 6lbs. of Brazil and 2 oz. of galls, pour one gallon of water, let them soak some time, then boil two hours, replacing the evaporated liquor with fresh water. Strain through a fine cloth upon 4lb. of gum senegal, and add one pint of the acetite of alumine, described in a former part of this article.

The addition of galls in the two preceding formulæ is supposed to import solidity to the colours in some way analogous to the operation of galling in silk and cotton dyeing, of which we shall have occasion to speak hereafter. Their constitution is otherwise the same as the berry and bark yellows, and most others of this class of colours.

Purple.

1. If the solution of tin directed for the pink in the last article be mixed with six times its bulk of a decoction of logwood poured whilst hot upon four ounces of sal ammoniac, and $2\frac{1}{2}$ lbs. gum senegal, a bright and lively purple will be obtained, the hue of which varies with the strength of the decoction and the proportion of solution of tin employed.

2. If instead of the solution of tin, the acetite of alumine before alluded to, be used in various proportions of one sixth, eighth, &c. purples differing in shade and intensity will be formed, applicable in some cases, but possessing less solidity than most of the colours already described.

The constitution of these compounds is the same as the preceding.

Olive.

Olives are variously compounded, according to the colour required.

1. By mixing chemical black in various proportions with berry or bark yellow. The depth and fulness of the olive depends on the quantity of black.

By a decoction of logwood added in greater or less quantity to the bark or berry yellow.

3. By the addition of copperas or nitrate of iron to decoctions of yellow or astringent colouring matters, such as bark, sumac berries, weld, &c. each of these produces a different hue, varying from the green olive to a drab or cloth colour. By mixing these decoctions in different proportions, and by varying their strength, and the quantities of copperas

or nitrate of iron added to each, a multiplicity of ſhades may be produced, of which it is impoſſible to convey any preciſe or definite ideas.

Theſe colours may be indifferently thickened with flour or gum, as beſt ſuits the work required, but when nitrate of iron is added to ſolutions containing gum, the inſtant coagulation that takes place muſt be counteracted by the addition of a portion of free nitrous acid. This effect ariſes from the ſtrong action exerted by metallic oxyds, at the maximum of oxydation, on mucilage or gum. When the decoction is very concentrated, and contains ſufficient colouring matter to engage the whole of the iron, this effect takes place in a leſs degree, but with ſolutions adapted to the production of the foregoing colours, a coagulation invariably takes place, unleſs counteracted by the preſence of a portion of free acid. Of this action of metallic oxyds on the ſolution of gum we ſhall further treat under the article Gum.

Claſs III.

In this claſs, the colouring matter is ſimply held in ſolutions, by an acid or alkali, and in that ſtate applied to the cloth without the intervention of any mordant.

The moſt important of theſe colours, is the alkaline ſolution of indigo which forms the topical or.

Pencil Blue.

1. Prepared ſolution of pot-aſh, by boiling together $7\frac{1}{2}$lbs. of quick lime, and 15lbs. of pot-aſh, in 10 gallons of water. Decant off the clear liquor, and ſeparate the remainder from the lime by means of the filter. To one gallon of this ſolution, add 1lb. of red arſenic, or orpiment, and 1lb. of fine indigo, both previouſly ground together in a mill with ſufficient water to form a thick paſte. Bring them up gradually to a boil, ſtirring carefully all the time, and then withdraw the fire. Thicken the ſolution with the beſt gum ſenegal, and for the pale ſhades of blue, dilute with one, two, &c. meaſures of gum-water.

The quantities and relative proportions of pot-aſh, orpiment, and indigo in a gallon of pencil blue vary conſiderably with different calico printers, and within certain limits, it appears, that the accuracy of theſe proportions is not of great importance. Hauſman, an intelligent French printer, employs 15lbs. of pot-aſh, 6lbs. of orpiment, and 8lbs. of indigo, to 12 gallons of water; and Oberkampf, proprietor of the celebrated manufactory of Tony, a ſtill greater proportion of indigo. Some printers add brown ſugar, and Bancroft has propoſed to ſubſtitute this for the orpiment, but without ſucceſs.

The ſolution, when recently made, is a yellowiſh green, but by expoſure to air, becomes gradually deeper, and at laſt blue. In this ſtate, it is wholly unfit for uſe, it contracts no union with the cloth, and is detached from it in the firſt operation of rinſing.

Of the peculiar nature and properties of indigo, we ſhall have occaſion to treat hereafter, under its proper head, at preſent it will ſuffice to obſerve, that it owes its colour and inſolubility in alkalies, to a portion of oxygen intimately combined with it. To render it ſoluble, therefore, it muſt be deprived of this oxygen, by the action of a ſubſtance having a more powerful affinity for it, and the ſulphuret of arſenic, or orpiment, is uſed for this purpoſe. Sulphate of iron, has a ſtrong affinity for oxygen, and is employed in de-oxygenating indigo for certain purpoſes; but the oxyd of iron not being ſoluble in alkalies, the ſolutions of indigo, formed by it, become quickly regenerated by the abſorption of oxygen, and cannot even be transferred from one veſſel to another. The ſulphuret of arſenic, on the contrary being very ſoluble in alkalies, preſents the double advantage of de-oxygenating the indigo, and of retaining it awhile in that ſtate, till on its application to cloth, it becomes expoſed ſo completely to the action of atmoſpheric air, as to regain its oxygen, colour, and inſolubility; and becomes fixed in its original or blue ſtate.

The copper coloured pellicles, which forms on the ſurface of pencil blue, and is renewed immediately on its removal, ariſes from the abſorption of oxygen, which, in ſpite of the action of the orpiment, is continually taking place. Hence ariſes that diſpoſition to unevenneſs, which is the great diſadvantage of this blue; the unavoidable expoſure to air of ſmall portions of the colour during its application with the pencil, reviving greater or leſs portions of indigo, and conſiderably reducing its ſtrength.

Moſt calico printers boil up the quicklime with the other ingredients, thinking its preſence not leſs neceſſary than the pot-aſh and orpiment; by this means a conſiderable portion of the ſolution of indigo is taken up by the ſediment, which careful waſhing does not wholly ſeparate. As the action of the lime is confined merely to the alkali, which it renders cauſtic, and capable of acting with greater force on the other ingredients; it is certainly much more economical to render the pot-aſh cauſtic before its addition to the indigo. A conſiderable waſte of colour is by this means prevented, and the ſolution may be thickened the moment the ebullition has ceaſed without waiting for the depoſition, which in the old mode takes place.

Orange.

The oxyd of iron, when diſſolved in acetous acid, forms one of the moſt uſeful and important mordants, as we have already ſhewn in the former part of this article. It is alſo capable of imparting a very pleaſing and permanent colour itſelf to cotton, when applied in ſolutions of tolerable ſtrength and purity, and forms the orange, buff, and gold colour of the calico printers.

1. The ſolutions of iron in vinegar, ſtrengthened by the addition of copperas may be uſed, but the pureſt and brighteſt gold colours are obtained from copperas and ſugar of lead, in the proportion of 5lbs. of the former, and 1lb. of the latter, to a gallon of water. When thickened with gum, and employed undiluted, it affords, when limed, a full ſtrong gold colour, and with two, four, ſix, &c. times its bulk of water, various ſhades of orange and buff, which reſiſt the action of air, alkalis, and ſoap; and are rather exalted than impaired by frequent waſhing. The addition of ſugar of lead, is to increaſe the ſtrength of the ſolution. A gallon of water diſſolves about 4lbs. of copperas. The addition of a pound of ſugar of lead, enables it to take up another pound nearly, and the ſtrength of the ſolution may be ſtill further increaſed by equal additions of the two ſalts. The operation of liming is a ſimple precipitation of the oxyd of iron on the cloth, and in caſes when this cannot be performed, the proportion of ſugar of lead muſt be increaſed to nearly that of the copperas. It is only the paler ſhades of orange, however, which are to be obtained this way. The deep gold colour before named, is not to be procured without the aid of a precipitant. Spaniſh brown is ſometimes added to a ſolution of iron, and employed in ſuch a caſe, but it contracts no union with the cloth, and is readily removed by ſimple waſhing and beating. When the orange, or gold colour, is thickened with flour, a ſmall portion of nitrate of iron muſt be added to the paſte, for reaſons we have aſſigned on a former occaſion.

2. A beautiful, but fugitive orange, is obtained by boil-

ing half a pound of annotta with 1lb. of cauftic pot-afh in a gallon of water, and thickening the liquor with gum. This colour acts powerfully on the fieves and blocks, which it very foon deftroys, and on this account, and alfo from its want of permanence is feldom ufed. It may either be fimply rinfed off, or firft paffed through water rendered flightly acidulous with fulphuric acid, or what is ftill better through alum-water. This operation is the very reverfe of liming, for here the colouring matter to be precipitated, being held in folution by an alkali, an acid muft be employed for that purpofe. The colour by this means is confiderably heightened, and when applied with the pencil, is ufeful in fome cafes where the other colours will fupport the action of alum-water without injury.

Borax, and even fpirits of wine, are fometimes added to the alkaline folution of annotta, and are fuppofed to contribute to its ftrength and fixity, though on what principle it is not eafy to difcover.

Green.

The oxyd of copper, diffolved in volatile alkali, affords a pale and delicate green, which is fometimes employed intermixed with other colours. Turnings of copper, or verdigrife, which is more generally ufed, may be digefted in a low heat with fpirits of fal-ammoniac. Care muft be taken that the heat be very moderate, and the veffel in which the folution is made, well ftopped, the ammoniac will otherwife be driven off, and loft. When the alkali has taken up as much copper as it can diffolve, the folution muft be thickened with gum, and applied with the block or pencil. In a few days the ammoniac evaporates and leaves the oxyd of copper on the cloth, which muft be rinfed to free it from the gum and fuperfluous colour.

The blues produced by alternate immerfion in copperas and lime, and alfo in the folution of indigo, by the fame fubftances, properly come under this clafs of colour, as they are folutions of colouring matter in lime and alkalis. As the proceffes by which they are applied, differ however very materially from all thofe that we have been treating of, they claim a feparate and diftinct notice. For the details of thefe operations, and the mode of preparing the paftes for bark and pale blue dipping, and the colours for China blue, we muft therefore refer our readers to the article *Dipping* Blue.

Colours, in *Dyeing*.—There are five fimple, primary, or mother colours, ufed by the dyers: from the mixture whereof all the other colours are formed; thefe are blue, red, yellow, black, and brown colour; each of which fee under their proper head, Blue, Red, &c.

Of thefe colours, mixed and combined, other colours are formed, which are infinitely various, according to the proportion of the different ingredients that are employed, or the proceffes by which they are blended. Thus a mixture of *blue* and *yellow* forms *green*, which is diftinguifhed by dyers into a variety of fhades, according to the depth of the fhade, or the prevalence of either of the component parts. Hence we have *fea-green*, *grafs-green*, *pea-green*, &c. &c. *Blue* and *red* form different fhades of *violet*, *purple*, and *lilac*. A mixture of *yellow* and *red* produces *orange*. Mixtures of *black* with other colours conftitute *greys*, *drabs*, and *browns*. For a more particular account of thefe and other colours; and the method of procuring and applying them; fee the article Dyeing. See alfo the preceding article.

The greateft perfection in the art of colours would be to find the means of preparing the fineft colours without the ufe either of acid or alkaline falts, which ufually fubject the colours to change, or elfe are apt to prey upon the cloth, canvas, &c. as we fee in verdigrife, the blue and green cryftals of copper, &c. It appears highly probable, that the Indians, for making the fine bright and durable colours, wherewith their chintzes and callicos are ftained, make ufe of metalline folutions; for fome ftained callicos, brought from thence, having been kept 40 or 50 years, the bright colours have been obferved to eat out the cloth, exactly in the fame manner as acid fpirits, which diffolve metals, are found to do.

Since thefe, then, are the inconveniences attending fuch colours, we ought to fearch for menftruums with which to extract colours, which are neither acid nor alkaline; and for fuch metalline oxyds, precipitates, or powders, as will not lofe their colours, by being well wafhed to get out their falts; to prepare certain metalline matters, by mere calcination, or the bare affiftance of fire; and laftly, to look out for native colours, wherein no faline matter abounds.

Mr. Geoffroy has given a very curious procefs for making two clear, fpirituous, inflammable liquors, which differ very little in tafte and fmell, and being mixt together give a fine carnation colour, without any fenfible fermentation.

To make the firft of thefe liquors, put a fmall handful of dried red rofes into a glafs bottle; pour on them rectified fpirit of wine, till it covers them an inch; let this ftand in a cold infufion four or five hours; then pour off the liquor, which will be clear and colourlefs, as when put on. The fecond liquor is made by dropping into rectified fpirit of wine, fo much oil of fulphur, by the bell, or fpirit of vitriol, as will be borne in it without giving it any very fenfible acidity when tafted. When thefe liquors are thus prepared, let a fmall quantity of the latter be dropped into fome of the former, and the whole will become of a fine carnation colour, though there is no fermentation, nor any other change perceived in it, but barely that of colour. If inftead of this laft liquor, there be added to the firft a few drops of the fpirit of fal ammoniac, the whole will become green.

Make a flight infufion of galls in water, fo as not to colour the water; make alfo a weak folution of green vitriol in water, fo that it may appear colourlefs; mix thefe two colourlefs liquors together, and an inky blacknefs is immediately produced; add to this black liquor a little oil of vitriol, and the liquor becomes pellucid and colourlefs again; then add to this a little falt of tartar, and the whole is black again.

Put a little bruifed camphor into rectified clear oil of vitriol; fhake the mixture, and it will become black, and the camphor will be diffolved; add to this a little water, and the liquor becomes clear, and the camphor is found feparated at top, in its own form, and native whitenefs.

Infufe lignum nephriticum in cold water, and pour off the clear liquor. This held up againft the light, appears of a fine yellow, but viewed from the light, of a beautiful blue: a little fpirit of nitre put to this liquor makes it lofe the power of reflecting the blue rays, and a little oil of tartar, afterwards added, recovers that power again.

Logwood, infufed in water, gives a red colour. Put to this a little fpirit of urine, and it becomes of a fine purple; and drop in afterwards a little fpirit of falt, and it becomes of a pale red.

A beautiful blue tincture may be made from filings of copper, by digefting them in fpirit of urine, hartfhorn, or the like. The addition of oil of vitriol deftroys the blue colour; and a little fpirit of falt turns it green

Pellucid oil of vitriol, mixed with pellucid oil of turpentine, produces a thick red balfam. And common oil, mixed with fair water, by means of a little wax, and continued

rubbing, turns into a thick white balfam, called cold cream.

Oil of vitriol, diftilled from quickfilver, leaves a white powder behind, which, if water be poured on it, becomes yellow.

Diffolve quickfilver in fpirit of nitre, and to part of it add fpirit of urine, and a white powder is precipitated; to another part of the folution add oil of tartar, and a yellow powder falls to the bottom.

Dip a new pen in fpirit of vitriol, and write with it on common blue paper, and the letters will appear red.

A pellucid folution of faccharum faturni being written with on paper, becomes invifible when dried; but the bare fumes of an infufion of quick lime, and orpiment, in water, will render the invifible writing black and legible.

Volatile falt of fal ammoniac, which is white, mixed with cryftals of copper, which are green, produce a fine purple.

The original and fimple, as well as the mixt, colours are producible by mixture. Thus, if the fun's rays pafs through two pieces of glafs, the one blue, and the other yellow, and be afterwards received upon a white paper, the colour there feen is green. The dyers make cloth blue with woad, and then turn it green by the yellow herb called luteola, or dyers' weed. To a yellow folution of gold in aqua regia add a blue one of copper in fpirit of urine, and the mixture becomes green. The painters every day practife this art of producing new colours by mixture.

Metalline and mineral matters are reducible to a confiderable degree of fubtlety, or fmallnefs of parts by fire, or dry calcination, fo as to leave them durably poffeffed of their native or adventitious colours. Thus lapis lazuli, by being calcined, becomes the fine rich blue called ultramarine; light ochre, by the fame treatment, becomes a light red, or flefh colour, the moft ufeful flefh-colour in painting. Lead, by calcination, becomes durably red, and iron durably brown; but a proper method feems wanting for the dry calcinations of the nobler metals, gold and filver; though, for the ufes of gilding, thefe are eafily prepared by dipping linen rags in their refpective folutions, and then drying, and burning them to afhes, whereby a dry and fine metalline powder is procured.

Comb Making

COMB *making*. Combs are not only made for the purpose of cleaning the hair, but for ornament: they are sometimes set with brilliant stones, pearls, and even diamonds; some again are studded with cut steel; these are of different shapes, and are used to fasten up the hair when ladies dress without caps. Combs may of course be had of all prices, from the value of a few pence to almost any sum. They are generally made of the horns of bullocks or of elephants, and sea-horses teeth, and some are made of tortoise-shell and ivory, others of box or holly-wood. The horns of bullocks are thus prepared for this manufactory: the tips are first sawn off; they are then held in the flame of a wood fire, this is called roasting, by which they become nearly as soft as leather. While in that state they are slit open on one side, and pressed in a machine between two iron plates; they are then plunged into a trough of water, from which they come out hard and flat; they are then sawn into lengths, according to the size wanted. To cut the teeth, each piece is fixed into a tool called a claw. The maker sits on a triangular sort of a stool to his work, and under him is placed the claw that holds the horn, ivory, &c. that is to be formed into a comb. The teeth are cut with a fine saw, or rather a pair of saws, and they are finished with a file. A coarser file, called a rasp, is used to reduce the horn, &c. to a proper thickness; and when they are completely made, they are polished with charcoal and water, and receive their last finish with powder of rotten stone. The process used for making ivory combs is nearly the same as that already described, except that the ivory is first sawed into thin slices. The best ivory comes from the island of Ceylon and Achen in the East Indies, as it possesses the property of never turning yellow; it is consequently much dearer than any other kind.

Tortoise-shell combs are much esteemed; and there are methods of staining horn, so as to imitate it, of which the following is one: the horn to be dyed is first to be pressed into a flat form, and then done over with a paste, made of two parts of quick-lime and one of litharge, brought into a proper consistence with soap-ley. This paste must be put over all the parts of the horn, except such as are proper to be left transparent, to give it a nearer resemblance to tortoise-shell. The horn must remain in this state till the paste be quite dry, when it is to be brushed off. It requires taste and judgment so to dispose the paste, as to form a variety of transparent parts, of different magnitudes and figures, to look like nature. Some parts should also be semi-transparent, which may be effected by mixing whiting with a part of the paste. By this means spots of a reddish brown will be produced, so as greatly to increase the beauty of the work. Horn thus dyed is manufactured into combs, and these are frequently sold for real tortoise-shell. The wages of journeymen in this business are from 21*s*. to 31*s*. per week.

In *Plate* XV. of *Mechanics* is represented a machine for cutting combs, for which Mr. William Bundy, of Pratt Place Camden Town, took out a patent in the year 1796, and the same is described in the Repertory of Arts. The frame A A, *fig*. 3 of the machine, is like a common lathe, containing a spindle, with a crank and fly-wheel, D, upon it, turned by the alternate motion of the treadle, B, which is moved by the workman's foot; E is a wheel fixed on the crank spindle, carrying a line in its groove, crossing between the cheeks of the lathe, and passing over the pulley, F, which turns on a centre fixed in the puppet, G; it has two holes in it to receive the horned catch, *a*, *fig*. 2, screwed on the end of an arbor, *b*, about seven inches in length, and half an

inch in diameter; this arbor is mounted between two circular brass plates, H, I, *fig.* 1, connected by three pillars, it carries as many circular steel cutters, or saws, K, *fig.* 4, as the comb to be cut is to have teeth. M, *fig.* 5, represents another arbor, which is fixed in the frame-plates, *fig.* 1, by its ends; it is triangular, and has a piece of steel, L, *fig.* 4 (called a guide), fitted on it between each saw, on the arbor, *b*. These parts are put together by first putting the end of the arbor, *b*, *fig.* 2, through the hole in the centre of the frame-plate, I, and screwing on the catch, *a*; the end of the arbor, *fig.* 5, is put into a square hole made in the plate, I, to receive it, and is fixed by a screw; a guide, L, *fig.* 4, is then put on the arbor, M, close against the shoulder, *d*; next a cutter, K, is put on the arbor, *b*, touching its shoulder, *e*; a piece of steel plate, N, called a guide-washer, is then put on the arbor, M, and another guide, L, close to it; the guide-washer is a little thicker than the cutter opposite it, so that the cutters each turn between two guides without touching them. These being in their places, a small washer, O, *fig.* 4, is put on the arbor, *b*, and a cutter, then a guide-washer and guide, on the arbor, M, and so on alternately, till the right number of cutters are put on; the sliding shoulder, *f*, *fig.* 2, is then taken, and with the octagonal nut, *g*, screwed fast up against the last cutter, put on the arbor, *b*, this will pinch all the cutters and washers between the shoulders, *e* and *f*, and hold them fast. The same is done to the arbor of the guides, and, lastly, the frame-plate, H, is put on the ends of the pillars, and screwed fast; the whole forming the resemblage shewn in *fig.* 1. The frame plates with the arbors, as in *fig.* 1, are now to be put in their place in the machine, *fig.* 3, the horns of the catch, *a*, going into two holes in the pulley, F, and the other end of the arbor, *b*, into a centre that goes up with a screw in the puppet, Q; the screws, *h*, *h*, are designed to steady the frame-plates (which hold the arbor of the guides) against the dove-tail, P P, supported by brackets projecting from the front of the cheeks, sufficiently to let the block, *i*, which slides in the dove-tail, and holds the comb, be drawn forwards to give room for the hand to put in or take out the combs clear of the cutter. To the base of the dove-tail is screwed a plate, holding one of the centres for a worm-wheel, *k*, whose axis is made of steel, and has its end cut with a deep thread-screw; the screw-end of this axis works in a centre, fixed to the base of the dove-tail, and the block, *i*, is cut away to pass clear over it and the threads of the screws, without touching them. The worm-wheel, *k*, is turned by an endless screw, on the arbor of the wheel, *r*, which receives its motion from the pulley, *t*, by an endless line. The block, *i*, which holds the comb, moves in the dove-tail, and is to carry the comb towards the cutters while cutting. As the screw on the axis of the wheel, K, is to carry the block up in lieu of a nut; a knife-edge, fastened to a small lever, *l*, moveable on a centre in the face of the block, is applied to it, and kept down (so that the knife-edge may take into the threads of the screw) by a catch similar to the latch of a door, which is released by pushing in a thumb-stud, and allows the spring, *o*, to throw up the lever, *l*, and disengage the screw, so that the block may be brought forwards in the dove-tail.

The piece of ivory intended to be cut into a comb, is put under a plate, *p*, and held down by two screws to the face of the block, which is in the same plane with the arbor of the cutters; the workman then puts down the knife-edge, and the catch keeps it so; he then turns the machine by his foot, and pushes the block towards the cutters (the comb resting close on the guides) till the knife-edge take the first thread of the screw, which turns round as before described, and pushes the block and comb up to the cutters, as far as the screw extends, and the cutters saw the teeth in the comb; the thumb-stud is then pushed in, and the spring, *o*, throws the knife-edge up, so that the block can be brought back by hand, and the comb taken out. The distance which the comb projects from the face of the block towards the cutters, and consequently the length of the teeth, is regulated by a straight edge of metal on the top of the block, *i*, under the plate, *p*, against which the back of the comb rests; it can be moved parallel to itself across the top of the block by two screws, (which are seen at the upper corners of the face of the blocks), for combs of longer or shorter teeth. The spindle of the crank has a wheel, R, on it, turning an arbor, S, by a line, which carries a set of cutters for pointing the combs. The arbor is shewn separately in *fig.* 6, and a cutter in *fig.* 7; it is made up in the same manner as the former one, and fastened by a screw, T; the ends of the teeth of the comb are applied to this cutter by hand, first on one side, and then on the other, till the points are made. This is performed to one comb, while the teeth are cutting in another.

Combustion

COMBUSTION, a fire, a burning, denotes the decomposition of certain substances, which are thereby called combustibles; accompanied with heat and light. The process of combustion, the various phenomena it exhibits, its astonishing effects, its infinite uses, and its devastations, have at all times, rendered it the principal object of human attention in all the various stages of life. The whole extent of civil economy, the preparation of food, as well as of almost all the articles of necessity and of luxury, most of the arts of more essential use to mankind, such as the manufactures of metals, of glass, of pharmacy, &c. depend almost entirely upon combustion. The inclemencies of the weather, and the dismal darkness of night, are removed by means of combustion. The most active instruments of destruction depend upon combustion. The greatest scenes of wonder, admiration, and terror, like the conflagration of towns, and the eruptions of volcanos, are those in which combustion is the sole actor.

Whilst the wants and the economy of the multitude, have at all times called forth their industry in devising easy methods of lighting and warming their apartments, of cooking their victuals, &c.; the calm contemplations of philosophers have endeavoured to investigate the cause or causes, the commencement, the progress, the various intensity, and the products of combustion. It is natural to suppose that their first ideas must have been extremely fanciful and incoherent; since the present theory, which rests upon the foundation of innumerable experiments and strict reasoning, is vastly different from any sort of hypothesis, which even the wisest philosopher would have been led to form, without the light of those experiments.

The first plausible theory of combustion was formed by Stahl, an eminent chemist. The striking difference between bodies combustible and incombustible; that is, between bodies that are, and those that are not susceptible of combustion; induced him to suppose that the combustibles were endowed with a peculiar principal of inflammability, which the incombustibles had not, and to this supposed principle he gave the name of *phlogiston*. According to this supposition, when combustibles were heated to a certain degree, they began to part with this phlogiston, and continued to burn as long as they had phlogiston to lose; after which, they remained in a state of incombustibility; hence, in the former state, those bodies were said to be phlogisticated, and in the latter they were said to be dephlogisticated. With certain bodies the combustion was attended with a separation of other components, so that afterwards they could not be brought back to their former state by the mere addition of phlogiston; but with other bodies, as for instance, with the metals, the processes of dephlogistication and phlogistication might be repeated without end. Thus, a piece of zinc in the metallic state was supposed to be loaded with phlogiston, therefore, when exposed to a sufficient degree of heat, it would burn, *viz.* it would part with its phlogiston, and would thereby be reduced into the

state of a calx, destitute of phlogiston, and of the metallic appearance; but by placing this calx in contact with bodies which contained abundance of phlogiston, in a proper situation, the calx would thereby be enabled to recover its phlogiston, and with it its metallic state and combustibility. It might then be burnt again, and so forth. This plausible theory was no sooner made known, than it was eagerly adopted by philosophers and chemists; so that for a long period it remained the most prevailing theory of combustion. But though the theory was universally adopted, the existence of the principle upon which it was established could not be proved. There was no exhibiting the phlogistion by itself; and it was merely a supposition that a body acquired or lost its inflammability, according as it was combined with, or deprived of, its phlogiston. A supposition which, on a closer examination of facts, was found inadequate to the explanation of the comcomitant phenomena. For instance, when a piece of zinc (and such was also the case with other combustibles as far as they might be subjected to experiments) of a determinate weight, was burnt and reduced to a calx, the weight of the calx was found to exceed the original weight of the zinc. It was, therefore, evident that it had acquired something ponderable, and this was utterly repugnant to the phlogistic theory, for by the loss of phlogiston it ought rather to have lost part of its original weight. In answer to this, a strange idea was suggested, namely, that the phlogiston was a principle of lightness; so that bodies became lighter by the addition of phlogiston and *vice versâ*. But this supposition, so singular and so repugnant to the general laws of gravitation, was soon abandoned by philosophers when a variety of decisive experiments, the concurrence of recent discoveries in other branches of philosophy, and a strict mode of reasoning, introduced a new theory of combustion, which is both supported by accurate experiments, and sufficient to account for the phenomena. One of the principal labours in the experimental investigation, and the full establishment of this new and rational theory, was the uufortunate Lavoisier, to whose genius, and to whose persevering industry, the scientific world must ever think itself indebted.

In order to render this theory more easily understood by the reader, we shall prefix the following experiment. Take a glass vessel of a cylindrical shape, having a stopple capable of excluding the entrance or exit of any air, and let the outside of this vessel be graduated, so as to divide its capacity into pretty small portions. Put into this vessel, full of common air, a piece of dry phosphorus of a determinate weight; close the vessel tight, and heat gradually that part of it in which the piece of phosphorus stands, by means of the flame of a candle. As soon as the phosphorus has been heated to a certain degree, it takes fire of itself, burning with a flame and thick white smoke; but it soon ceases to burn. Suffer the vessel to cool, and the smoke will fall in the form of flakes, if the vessel and the air contained in it were quite dry, otherwise these flakes will melt in the moisture. If, in this experiment, the vessel be weighed before and after the combustion, it will be found precisely of the same weight. When the vessel is cooled to the actual temperature of the atmosphere, plunge the aperture of it under water, and in that situation remove the stopple. You will find that the water rises in it, which shews that a portion of the air has been destroyed or absorbed; in short, it has disppeared. By measuring the height of the water risen within the vessel, which is indicated by the graduation on the outside of it; in general, it will be found that about one quarter of the original quantity of air has disappeared; and the remaining air will be found unfit for the combustion of phosphorus or of any other combustible; and is likewise unfit for the respiration of animals, so that if a bird, a mouse, or any other animal be confined in it, death will soon ensue. If the water which has rushed into the vessel be examined, it will be found to have contracted a sour taste indicating that an acid has been generated. If the vessel, instead of being opened in water be inverted and opened in quicksilver, then the flakes which in the preceding experiment were dissolved by the water, will now remain on the surface of the quicksilver. This is the acid of phosphorus, and if it be carefully gathered and weighed, it will be found together with the remaining phosphorus (if part of it remains unburned), equal to the weight of the original quantity of phosphorus together with the weight of the air that has disappeared. Therefore it is evident that the whole process of combustion consists in a decomposition of the purest part of respirable or atmospherical air; the pure part of it, which is about a quarter of the whole, is decomposed, its base is absorbed by the combustible, and generally communicates to it acid properties, in consequence of which that portion of the atmospherical fluid has been called oxygen gas, from the Greek; meaning the acidifying principle. Therefore, in combustion, the decomposition of the oxygen gas is effected by the burning body, when this body has been heated to a certain degree, which degree varies with the nature of the body. The base of the oxygen gas is absorbed and fixed by the burning body, which has thereby its weight increased, and its nature changed; whilst the caloric being disengaged, passes off in the state of sensible heat, and sometimes with such a portion of light as gives the appearance of red or white heat. Acids in general are formed from the absorption of oxygen during combustion. See OXYGEN GAS.

When the combustion is accompanied with red heat, but not with flame, it is called *ignition*. But ignition may also be applied to incombustible substances, for these may be rendered red or white hot, without suffering any decomposition. When a vapour arising from the heated body burns over it, it is then called *inflammation*; and when the inflammation is rapid and attended with noise, it is called *detonation*. Having now compendiously stated the new theory of combustion, it is necessary to add several necessary remarks respecting every part of it, which could not be intermixed with the theory without rendering it confused and less intelligible.

In the first place, since the process of combustion consists in a decomposition of oxygen gas, the generalizing spirit of modern philosophy includes every process, in which oxygen gas is decomposed, under the general name of combustion; thus, animal respiration, in which this gas is decomposed, its base absorbed, and heat evolved; may be reckoned amongst the processes of slow combustion. See RESPIRATION. The gradual absorption of oxygen by metallic bodies may also be reckoned amongst those processes.

Since combustion consists in a decomposition of oxygen gas, it naturally follows that without oxygen no combustion can take place. The oxygen, however, may be contained in other substances, in consequence of which those substances become capable of assisting combustion. Now there are seven of those substances, which, from their containing oxygen, are called *supporters* of combustion; and these are oxygen gas, atmospheric air, nitrous oxyd, nitric oxyd (which is procured by digesting copper and mercury in diluted nitrous acid, and collecting the gas which is extricated), nitric acid, oxygenized mu-

riatic acid, and hyperoxygenized muriatic acid. See the nature of those substances under the article GAS. It also follows that with a given combustible, the quickness of the decomposition is proportionate to the supply of oxygen, which shews the reason why a fire is increased by blowing common air, and much more by blowing oxygen gas upon it. But cæteris paribus with different combustibles, the fire is strongest when the combustible has the strongest attraction for oxygen. The flame of hydrogen gas urged by oxygen gas is reckoned to produce the most intense heat.

A combustible body, though exposed to oyxgen, generally requires to be heated to a certain degree before the combustion commences. That degree varies with the nature of the body, and the purity of the oxygen; so much so that some of them, though not many, take fire immediately on being exposed to some of the above-mentioned supporters of combustion in the common temperature of the atmosphere, whilst others must be heated to a red and even to a white heat, before the decomposition takes place.

When the combustion has once commenced, the heat or caloric, in the form of sensible heat, which is extricated from the oxygen gas, raises the temperature of the adjacent parts of the combustible to that degree which is necessary for its combustion, and the heat evolved by the burning of this part heats the next and so on. But this is not the case with all sorts of combustibles; for some there are which must be kept up at a given high temperature in order to effect their combustion, and a diamond is of this sort. However the nature of combustibles in this respect varies according to the purity and quantity of oxygen. For instance, if a slender steel wire be exposed to the flame of a candle in common air, that part of it only will burn, which is acted upon immediately by the flame; but if the same wire be lighted by means of a bit of tinder, and then be plunged in a vessel full of oxygen gas, it will burn successively to the very end, like a slip of paper; exhibiting a remarkable bright light, and very considerable heat.

Of the simple bodies of nature, the chemists reckon three combustible ones, and two that are incombustible. The former are sulphur, phosphorus, and hydrogen; and the latter are azote and muriatic acid; but amongst the compound bodies, the combustibles are much more numerous. Such are oils, acids, and a vast variety of others which being of a fluctuating nature need not be particularly specified.

A variety of experiments, which may be found under the article GAS, prove that gasses owe their elastic nature to a considerable quantity of caloric, which must necessarily combine with their base, in order to assume the aerial form. Therefore, when, in consequence of the superior affinity of the combustible for oxygen, the oxygen gas is decomposed, and its base condensed, the caloric, which was necessary to its aerial form, being set at liberty, appears in the form of sensible heat; hence the heat which accompanies combustion is naturally supposed to proceed from the oxygen gas; and the quantity of it varies according to the rapidity of the process, so much so that in certain processes like the decomposition of oxygen effected by metallic substances in common air, it is not attended with any sensible degree of heat; for the heat evolved, being very slight, is instantly dissipated among the surrounding bodies.

With certain combustible bodies a peculiar process takes place. It is a remarkable slow process of spontaneous combustion. The body, by attracting oxygen from the atmosphere, becomes thereby gently heated, in consequence of which its affinity to oxygen is increased, a greater decomposition of the latter ensues, more heat is evolved, and thus the process is gradually accelerated until flame and visible combustion take place. Such is sometimes the case with hay, the saw-dust of certain woods, and various other substances. The well known mixture of iron filings and sulphur moistened with a little water, is an instance of this sort; for if this mixture be buried a little below the surface of the ground, it will of itself, after the lapse of several hours, burst forth in a state of ignition. This experiment has been generally called the *artificial volcano*.

Though heat in combustion is derived from the oxygen gas, the derivation of light is not so evident. It has been for a long time supposed that this element also was one of the components of oxygen gas; but the observations made respecting the light yielded by several bodies when they are slightly heated, or even spontaneously, and that some of them yield much more light than others, seem to prove, that light forms a component principle of most bodies, and that it is evolved from the combustible. It is likely, however, that part of it may be derived from the oxygen also.

The following list of bodies subject to spontaneous inflammation is given by professor Bartholdi; meaning the inflammation occasioned by different bodies acting upon each other, without the aid of another body previously in a state of combustion.

1. Friction. Thus pieces of wood rubbed against each other are thereby inflamed. The best for this purpose are box-wood rubbed against mulberry, or laurel against poplar, or against ivy, &c. It is in consequence of friction that the wheels and axletrees of carriages sometimes take fire, when they are not sufficiently greased. In turning also, pieces of wood sometimes take fire.

2. The action of the sun's rays concentrated by lenses, or concave reflectors, or even by plane reflectors, provided their reflections be thrown upon the same spot. See BURNING-*Glass*, and REFLECTORS.

3. The sudden slacking of quicklime has sometimes been known to produce the combustion of adjacent bodies.

4. The fermentation of animal and vegetable substances. Thus great accumulations of hay, turf, or flax, and hemp, heaps of linen rags in paper mills, &c. take fire, provided they are not quite dry; for without moisture, fermentation and the consequent evolution of heat cannot take place.

5. The accumulation of animal and vegetable substances covered with an oil, especially when the oil is of a drying quality. Thus lamp-black mixed with linseed oil is apt to take fire, and an earth of a brown colour, called the *black wad of Derbyshire*, sprinkled over with a little linseed oil, takes fire and appears red-hot like burning small coal, in about an hour's time.

6. There are several substances, which have the property of inflaming spontaneously, increased by torrefaction. Coffee, French beans, lentils, &c. are of this nature.

7. Sulphurated and phosphorated hydrogen gas. The cause of subterraneous fires and volcanoes in general, is attributed to the decomposition of pyrites, or metallic sulphurets, buried in the interior of the earth. These pyritous masses are decomposed by the contact and concurrence of water and air, and the decomposition is always accompanied with a great extrication of caloric, and a disengagement of a very inflammable gas, called *sulphurated hydrogen gas*. This gas inflames at an elevated temperature, and communicates the inflammation to the sulphur of the pyrites, to the coal and other bituminous matters, which generally accompany it.

8. Sulphuret and phosphuret of lime and of potash, formed in the combustion of several vegetables.

9. Phosphorus sometimes contained in charcoal.

The laſt particulars which we need take notice of, concerning the theory of combuſtion, are its products. But theſe muſt not be miſtaken for thoſe bodies which exiſted in certain combuſtibles, and have been left by themſelves when the other components of the combuſtible have been ſeparated, ſuch as earthy particles, &c. The real products of combuſtion are thoſe which did not exiſt before, and theſe, upon a ſtrict examination, will be found to be either water, or an oxyde, or an acid. Water conſiſts of oxygen and hydrogen. See WATER. An oxyde is a compound of the combuſtible with oxygen, but not ſuch as to poſſeſs decided acid properties, (and the proceſs is called *oxydation*), or an acid, which conſiſts of the acidifiable part of the combuſtible, combined with oxygen ſufficiently to give it decided acid properties. Thus, the combination of carbon and oxygen forms the carbonic acid gas, and this is produced in almoſt every combuſtion, alſo in reſpiration. &c.

Commerce

COMMERCE, the interchange of commodities, or the disposal of produce of any kind for other articles, or for some representative of value for which other articles can be procured, with the view of making a profit by the transaction. The term is usually restricted to the mercantile intercourse between different countries; the internal dealings between individuals of the same country, either for the supply of immediate consumption, or for carrying on manufactures, being more commonly denominated *trade*.

The mutual convenience of an exchange of commodities, must have been evident almost as soon as any part of mankind had acquired an idea of distinct property; the difficulty of communication between different countries must, however, have long rendered commercial intercourse very limited and uncertain. The dangers attending long journies induced those who engaged in trading to distant parts, to associate together for mutual assistance and defence; and these companies of merchants, or caravans, were well adapted for the improvement of commerce, from the information which the individuals composing them would communicate to each other, and the connections they might occasionally form. In the book of Genesis, mention is made of the companies or caravans of Ishmaelite merchants trading in spices from Gilead into Egypt; to one of whom Joseph was sold, about 620 years after the flood. But this mode of communication between different countries was insufficient for the enterprising spirit of commercial adventurers; remote countries cannot convey their commodities by land to those places where, on account of their rarity, they are most desired, and consequently become most valuable. It was not till some progress had been made in the art of navigation, that the power was acquired of transporting with facility the superfluous stock of one part of the earth to supply the wants of another part, and that the active spirit of commerce could extend its multifarious concerns to all the known parts of the globe.

The Egyptians, soon after the establishment of their monarchy, are said to have opened a trade between the Arabian Gulph or Red Sea, and the western coast of the great Indian continent. The commodities which they imported from the east, were carried by land from the Arabian Gulph to the banks of the Nile, and conveyed down that river to the Mediterranean: but the maxims and manners of Egypt were inimical to commerce, and this profitable traffick soon declined.

The situation and circumstances of the Phenicians naturally led them to look to commerce as the only source from which they could derive opulence or power; and accordingly, the foreign trade carried on by them, particularly from Sidon and Tyre, became more extensive and important than that of any state in the ancient world. Their ships not only frequented all the ports in the Mediterranean, but they were the first who ventured beyond the ancient boundaries of navigation, and passing the streights of Gibraltar, visited the western coasts of Spain and Africa. They revived a commercial intercourse with Arabia and the continent of India, on the one hand, and with the eastern coast of Africa on the other; the cargoes which they purchased in Arabia, Ethiopia, and India, being landed at Elath, the safest harbour in the Red Sea towards the north; thence they were carried by land to Rhinocolura, the distance not being very considerable, and, being re-shipped in that port, were transported to Tyre, and distributed over the world.

The wealth which the Phenicians acquired by monopolizing the commerce of the Red Sea, incited their neighbours, the Jews, under the prosperous reigns of David and Solomon, to aim at being admitted to some share of it. Solomon fitted out fleets, which, navigated by Phenician pilots and mariners, sailed from the Red Sea to Tarshish and Ophir, from whence they brought such valuable cargoes as suddenly diffused wealth and splendour through the kingdom of Israel. But the institutions of the Jews were by no means favourable to commerce, which was never carried to any great extent by them while they inhabited Judea.

The Carthaginians applied themselves to commerce and navigation with ardour, ingenuity, and success; but as the Phenicians had engrossed the commerce of India, their adventures were chiefly made to the west and north. Following the course which the Phenicians had opened, they extended their voyages beyond the shores of the Mediterranean, visiting not only all the coasts of Spain, but those of Gaul, and penetrating at last to Britain. They made voyages of discovery in different directions, and thus established a commercial intercourse with places which before were wholly unknown; but whatever knowledge of this kind they acquired, it was concealed from the inhabitants of other states with the utmost care.

The Greeks, although their country was almost encompassed by the sea, which formed many spacious bays and commodious harbours, and though it was surrounded by a number of fertile islands, were, notwithstanding such a favourable situation, a long time before they attained any degree of perfection in navigation. They scarcely carried on any commerce beyond the limits of the Mediterranean. Their chief intercourse was with the colonies of their countrymen planted in the lesser Asia, in Italy, and in Sicily. They sometimes visited the ports of Egypt, of the southern provinces of Gaul, and of Thrace, or passing through the Hellespont, they traded with the countries situated around the Euxine sea. The expedition of Alexander into the east considerably enlarged the geographical knowledge of the Greeks. He had observed the resources which commerce creates, in the exertions of the republic of Tyre, and therefore it became part of his plan to render the empire which he proposed to establish, the centre of commerce as well as the seat of dominion. With this view, he founded Alexandria near one of the mouths of the Nile, that, by the Mediterranean sea, and the neighbourhood of the Arabian gulph, it might command the trade both of the east and west. This situation was so judiciously chosen, that Alexandria soon became the chief commercial city in the world. Not only during the subsistence of the Grecian empire in Egypt and

in the eaſt, but amidſt all the ſucceeding revolutions of thoſe countries, commerce, particularly that of the Eaſt Indies, continued to flow in the channel which the ſagacity and foreſight of Alexander had marked out for it, till the diſcovery of the navigation by the Cape of Good Hope opened a more expeditious and independent channel to all the maritime ſtates of Europe.

In the early periods of the Roman hiſtory, commerce appears to have been much neglected and undervalued; it ſeems to have been thought a degrading employ by this military people, and to have been left almoſt entirely in the hands of the natives of the countries they conquered. The extent, however, of the Roman power, which included the greateſt part of the known world, the vigilant inſpection of the Roman magiſtrates, and the ſpirit of the Roman government, no leſs intelligent than active, gave ſuch additional ſecurity to commerce, as animated it with new vigour; and, as ſoon as the Romans acquired a taſte for the productions of other countries, commerce, particularly the trade with India through Egypt, was puſhed with new vigour, and carried on to a greater extent. The pilots who ſailed from Egypt to India firſt ventured to quit ſight of the ſhore, and depending wholly on the trade winds, boldly ſailed from Ocelis at the mouth of the Arabian gulph, acroſs the ocean, to the coaſt of Malabar, returning with the eaſtern monſoon, and thus procuring the ſpices and other rich commodities of the continent and iſlands of the farther India, which were brought to the port of Muſiris by the Indians themſelves. The commerce thus carried on will appear conſiderable even in the preſent age, as the trade with India is ſaid to have drained the Roman empire every year of more than four hundred thouſand pounds, and that one hundred and twenty ſhips ſailed annually from the Arabian gulph to that country. The reign of Auguſtus was very favourable to commerce, as the peace which then prevailed over the civilized parts of the world, enabled the merchants to purſue it unmoleſted. Under Tiberius we find the Romans extending their protection to the north, and the town of Havern, the moſt ancient in Frieſland, founded. Under Nero, the capital of England is firſt mentioned as a conſiderable place. Tacitus, who lived for ſome time at London, ſays it was famous for its many merchants, and plenty of its merchandize. Rome, however, as the ſeat of wealth and luxury, continued to be the metropolis of the commercial world, until the fourth century, when Conſtantine removed the ſeat of empire to Conſtantinople, and made it the emporium of commerce. This city was undoubtedly well adapted for that honour; it was favoured by nature with a fine climate, and in a moſt advantageous ſituation for carrying on an extenſive correſpondence with every part of the world then known.

The invaſion by the northern nations in the fifth century, not merely arreſted the progreſs of commerce, but effectually diſſolved all commercial connections, and deprived the merchants of any market for their commodities. Europe became parcelled out into many ſmall and independent ſtates, differing from each other in language and cuſtoms; no intercourſe ſubſiſted between the members of theſe divided and hoſtile communities; their mode of life was ſimple, they had few wants to ſupply, and few ſuperfluities to diſpoſe of. Cities, in which alone an extenſive commerce can be carried on, were few, inconſiderable, and deſtitute of thoſe immunities which produce ſecurity or excite enterpriſe. It became diſagreeable and dangerous to viſit any foreign country, and thus the knowledge of remote regions was loſt; their ſituation, their commodities, and almoſt their names, were unknown. The preſervation of Conſtantinople from the general deſtruction, however, prevented commercial intercourſe with diſtant nations from ceaſing altogether. In that city the knowledge of ancient arts and diſcoveries was preſerved; a taſte for ſplendour and elegance ſubſiſted; the productions of foreign countries were in requeſt; and commerce continued to flouriſh there when it was almoſt extinct in every other part of Europe. The merchants of Conſtantinople did not confine their trade to the iſlands of the Archipelago, or to the adjacent coaſts of Aſia; they took a wider range, and following the courſe which the ancients had marked out, imported the commodities of the Eaſt Indies from Alexandria. When Egypt was torn from the Roman empire by the Arabians, the induſtry of the Greeks diſcovered a new channel, by which the productions of India might be conveyed to Conſtantinople. They were carried up the Indus, as far as that great river is navigable; thence they were tranſported by land to the banks of the river Oxus, and proceeded down its ſtream to the Caſpian ſea. There they entered the Volga, and ſailing up it, were carried by land to the Tanais, which conducted them into the Euxine ſea, where veſſels from Conſtantinople waited their arrival. This extraordinary and tedious mode of conveyance, Dr. Robertſon obſerves, is a proof not only of the violent paſſion which the inhabitants of Conſtantinople had conceived for the luxuries of the eaſt, and of the ardour and ingenuity with which they carried on commerce, but it demonſtrates, that during the ignorance which reigned in the reſt of Europe, a knowledge of remote countries was ſtill preſerved in the capital of the Greek empire. Robertſon's Hiſt. Amer. vol. i.

The devaſtations of the Huns in Italy induced many of the richeſt inhabitants of the country near the bottom of the Adriatic, to fly with their beſt effects into the numerous ſmall ſandy iſles lying amongſt the ſhallow waters near the ſhores of the continent; on which iſles, about ſeventy-two in number, they built ſuch habitations as their circumſtances would admit; and here by degrees aroſe the celebrated commercial city of Venice. Neceſſity firſt obliged them to devote themſelves to commerce, the earlieſt branch of which was naturally the fiſheries. Their next commercial object was the manufacture and exportation of ſalt. Thus by the application of its inhabitants, and the ſecurity of its ſituation, Venice gradually became the general magazine for the merchandize of the neighbouring continent, to which the many rivers that fall into the Adriatic ſea greatly contributed; and as the Venetians in time became the carriers of this merchandize into diſtant countries, they were enabled to bring back raw materials for various manufactures which greatly enlarged their commercial dealings.

In this manner, Venice firſt, and Genoa, Florence, and Piſa afterward, from inconſiderable places became populous and wealthy cities, and laid the foundation for the revival of commerce throughout the Mediterranean, which, in proceſs of time, was extended to the countries of Europe without the ſtreights of Gibraltar. The free cities of Italy, were, for ſeveral centuries, the only places in Europe, weſt of the Eaſtern or Greek empire, which had any conſiderable commerce, or any valuable manufactures for the ſupply of other nations. Their merchants frequented Aleppo, Tripoli, Alexandria, and other ports of Syria and Egypt, where they procured the produce of India; and viſiting the maritime towns of Spain, France, the Low Countries, and England, by diſtributing their commodities over Europe, communicated to its various nations ſome taſte for the valuable productions of the eaſt, as well as ſome ideas of manufactures and arts, which were then unknown beyond the precincts of Italy.

The first mention of the city of Antwerp, afterwards so famous for its trade, is in the year 517, when Theodoric expelled the Danes from it. Some towns in England, as Chichester and Abingdon, are said to have been founded about this time, which shews that trade and manufactures were gaining ground in this country.

The unsettled state of Europe, arising from the fierce and restless disposition of the barbarous tribes who had taken possession of the western empire, caused for several centuries a great stagnation of commercial intercourse. Venice however continued to improve its commerce, and London became "a mart town of many nations, which repaired thither by sea and land." Some of the Italian cities began to assume a degree of independence, and several towns were founded in Germany and Flanders, which afterwards became of much commercial importance. The commerce of Europe revived a little under the government of Charlemagne, who, among other endeavours to promote it, is said to have formed a project for uniting the two great rivers of the Rhine and the Danube, and thus forming a communication between the German ocean and the Black sea, without sailing up the Mediterranean. But his engineers had not sufficient skill to overcome the difficulties they met with, and the undertaking was soon relinquished. In a letter from this prince to Offa, king of Mercia, he grants leave for such English as went in pilgrimage to Rome, to pass through his dominions free; but such as travelled for the purposes of trade were to pay the customary tolls; and promises that the merchants should have legal patronage and redress of grievances. These merchants were probably persons who carried their whole stock with them, which of course could not be of any very great amount.

The establishment of Christianity in Germany produced a much more intimate and regular correspondence between the north of Europe, and the earlier Christianized countries of Italy, France, Spain, and Britain; so that their superfluities and produce were mutually communicated to each other, while Germany received by degrees, from its intercourse with those countries, considerable improvements with respect to agriculture, mining, vine-dressing, manufactures, and the arts, more immediately conducive to the comforts of civilized life. It considerably increased the cities and towns, where cathedral churches and houses for the bishops and clergy were erected. Thus the propagation of Christianity greatly favoured the advancement of commerce in the north of Europe; while Charlemagne by his conquest of Italy, and by rebuilding and restoring many of the decayed cities of that country, inspired those cities with the spirit of commerce, manufacture, and navigation, for which they became in after times so justly famous. This period may be considered as the first dawn of the revival of commerce in Europe; for although subsequent to this time the Saracens or Moors, and the Normans, by their ravages and conquests in various parts, greatly obstructed and retarded its progress, yet in spite of all oppositiom, the free cities in both the extreme parts of Europe in consequence of the increase of their wealth and population from the encouragement of commerce, gradually arose to very considerable importance.

In the tenth century, the commercial intercourse which the Germans had previously cultivated with the neighbouring states was much increased by the discovery of valuable silver mines at Goslar in Saxony, which occasioned other parts of Germany to be explored for mines with considerable success. The woollen manufacture of Flanders began to acquire some degree of importance, being much encouraged by Baldwin, third earl of Flanders, who invited into the country all manner of handicraftsmen for making all sorts of manufactures, to whom he granted great privileges. He also established annual fairs, and fixed markets on stated days of the week at Bruges, Courtray, Torhout, Mont-Cassel, and other places, where merchants could exchange their goods for others; for "by reason of the scarcity of money at that time, the Flemings dealt mostly by permutation, or barter of one kind of merchandize for another; which we read was also the practice of almost all the Germans and Sarmatians."

The republic of Venice had now acquired so much wealth and strength by the great extention of her commerce, as to have become a formidable political state, and having annexed to their dominions many cities and towns on the east coast of the Adriatic sea, the doge of Venice assumed the title of duke of Dalmatia. They established a regular commercial intercourse with the Saracens of Egypt and Syria, "countries ever famous for the production of rice, sugar, dates, senna, cassia, flax, linen, balm, perfumes, galls, wrought silk, soap, &c. besides the rich spices and precious stones of India, brought to those two countries; with all this rich merchandize, the Venetians now traded all over the western parts of Europe, to their immense profit." They obtained from the Greek emperors a freedom from all customs and taxes in their empire; and in the year 996 the emperor Otho III. likewise granted them various privileges, with a right to set up fairs in several parts of Germany, where they carried on a vast commerce.

The crusades contributed materially to the extension of commerce during the 11th and 12th centuries. The Genoese, the Pisans, and the Venetians, furnished the transports necessary to carry the vast armies that embarked on these wild enterprizes: they also supplied them with provisions and military stores. Besides the immense sums which they received on this account, they obtained commercial privileges and establishments of great consequence, in the settlements which the crusaders made in Palestine, and in other provinces of Asia. From these sources they acquired great wealth, and a proportionate increase of power. By the expeditions into Asia, the inhabitants of all the states of Europe had an opportunity of observing the manners, the arts, and the accommodations of people more polished than themselves. The adventurers who returned from Asia communicated to their countrymen the ideas which they had acquired, and the habits of life they had contracted by visiting more refined nations. The Europeans began to be sensible of wants with which they were formerly unacquainted; and such a taste for the commodities and arts of other countries gradually spread among them, that they not only encouraged the resort of foreigners to their harbours, but began to perceive the advantage and necessity of applying to commerce themselves.

The great commercial progress of the city of Lubeck soon caused other towns to be founded in the neighbourhood of the Baltic; which, suffering much from the occasional attacks of neighbouring powers, and the depredations of pirates, were induced to enter into an association for their mutual safety, and the protection of their navigation. Thus was gradually formed the famous Hanseatic confederacy, which made so great a figure in the commercial history of several succeeding centuries, and of which Lubeck was from the first considered as the director or head. Werdenhagen fixes on the year 1169 for the first of this confederacy, which consisted of the twelve following towns on the Baltic shore: viz. Lubeck, Wismar, Rostock, Straelsund, Grypeswald, Anclam, Stetin, Colberg, Stolpe, Dantzick, Elbing,

and Koningfberg; though probably not all of them at the firft; as fome of them do not appear to have been founded till a later period. Lambecius, librarian to the emperor Leopold, is of opinion, that the Hans-league did not properly commence till after the league between Lubeck and Hamburgh in 1241, at which time the towns comprehended in this affociation were in poffeffion of all the commerce of the fouth fhores of the Baltic, from Denmark to the bottom of the gulph of Finland, befides an extenfive commerce to more diftant parts. About this time the commerce of Norway began to acquire fome degree of importance, and in a treaty between the monarch of that country and Henry III. of England, in 1217, it was agreed that their refpective ftates fhould be free for merchants and others on both fides.

At the beginning of the 13th century, the German merchants of the Steel-yard engroffed all the foreign commerce which then exifted in England, which at that time had very few merchants, and fewer fhips of her own. About 1250, however, a fociety of Englifh merchants was formed, who are faid to have had privileges granted to them in the Netherlands, by John duke of Brabant; whither they had begun to refort with Englifh wool, lead, and tin, bringing in return fine woollen cloths, linen, and other articles. From this fociety, the company ftyled "Merchants of the ftaple of England" took its rife. In 1274, a treaty was concluded with the earl of Flanders for the fettlement of fome commercial difputes which exifted between the two countries.

France at this period poffeffed very little foreign commerce, but in the cities of Italy it had increafed greatly. The republic of Genoa was in its meridian glory, being the greateft maritime power then exifting. Even Venice, great as it was now become, was eclipfed by Genoa, which, towards the conclufion of this century, had reduced the republic of Pifa, till then alfo powerful at fea, to the loweft ebb of fortune, never again to rife to greatnefs, and foon to lofe her independence.

A new æra was now about to commence in commercial hiftory. The difcovery of that valuable, but now familiar inftrument, the mariner's compafs, Dr. Robertfon obferves, may be faid to have opened to man the dominion of the fea, and to have put him in full poffeffion of the earth, by enabling him to vifit every part of it. But the effects of this difcovery were not fo fudden or extenfive as might be expected. The ufe of the compafs enabled the Italians to perform the fhort voyages to which they were accuftomed, with greater fecurity and expedition, but near half a century elapfed, before navigators ventured into any feas which they had not been accuftomed to frequent. One of the firft fruits of fuch adventures, was the difcovery of the Canary iflands by the Spaniards.

Many of the princes of Europe were now becoming more fenfible of the importance of commerce, which led them to enter into treaties for its regulation and defence. Edward I. in 1302 publifhed his famous charter ftyled Charta Mercatoria, by which "The merchants of Almaine, France, Spain, Portugal, Navarre, Lombardy, Florence, Provence, Catalonia, Aquitaine, Thouloufe, Flanders, Brabant, and of all other foreign parts, who fhall come to traffic in England, fhall and may fafely come with their merchandize into his cities, towns, and ports, and fell the fame, by wholefale only, as well to natives as to foreigners." Some particular articles they were allowed to fell by retail; and they were to export any goods they might want from England on paying the ufual cuftoms, except wine, which could not be exported without a fpecial licence. The countries here mentioned fhew the parts to which the commerce of England was at that time chiefly confined; and a very good idea of its extent may be gained from the following account of the exports and imports, in the 28th year of Edward III. from a record in the Exchequer.

Exports.	£.	s.	d.
31,651¼ facks of wool, at fix pounds per fack, and 3036 hundred weight and 65 fells, each hundred weight being 6 fcore, at forty fhillings per hundred weight, with the cuftoms, &c. thereon, amounted to - - -	277,606	2	9
Leather, with its cuftom - - - - - -	96	2	6
4774½ coarfe cloths, at 40 fhillings each, and 8061½ pieces of worfted, at 16*s*. 8*d*. per piece - - - - - - -	16,266	18	4
Cuftoms thereon - - - - - - - - -	215	13	7
Total Exports, with the duties thereon	294,184	17	2

Imports.			
1831 fine cloths, at 6*l*. per cloth, which, with the cuftoms, comes to -	11,083	12	0
397¾ hundred weight of wax, at 40 fhillings per hundred weight, which, with the cuftoms, comes to - - - -	815	7	5
1829½ tons of wine, at 40 fhillings per ton, which, with the cuftoms, comes to - - - - - - - - - - - -	3,841	19	0
Linen cloth, mercery, grocery, and all other wares whatever - - - - -	22,943	6	10
On which the cuftom was - - - - -	285	18	3
Total Imports, with the duties thereon	38,970	3	6

Thus, as fir William Temple obferves, "when England had but a very fmall foreign commerce, we were rich in proportion to our neighbours, by felling fo much more than we bought." It is not very probable, however, that the excefs of the exports was generally fo great as is here ftated.

The materials of commerce were now increafing by the improvement of manufactures in various parts of Europe; while the difcoveries of the Portuguefe on the coaft of Africa, and in the adjacent feas, excited a more enterprifing fpirit of mercantile adventure, and at length, in 1487, led to the difcovery of the Cape of Good Hope, which they doubled about ten years after, and thus accomplifhed the firft regular voyage to the Eaft Indies. About the fame time alfo was accomplifhed the great difcovery of the weftern continent. Thefe events, which filled the world with aftonifhment, and gave rife to an infinity of new fpeculations, have fince fupplied it with a prodigious increafe of wealth, and with many new and excellent materials for the immenfe additional commerce which has thus accrued to all the ftates of Europe.

The whole of the vaft regions difcovered in the Eaft and Weft, was by the papal authority divided between the Spaniards and Portuguefe. The former firft made herfelf miftrefs of the iflands, and next of the principal part of the continent of America; in confequence of which the cities of Seville and Cadiz became the ftore-houfes for the riches of the newly-difcovered weftern world. Portugal purfued her commerce and rapid conquefts in the Eaft Indies, fo that

Lisbon soon became (what the now declining city of Venice had been for many centuries past) the great magazine for all the rich productions of the East. They had also discovered Brasil in South America, which soon became an almost inexhaustible fund of wealth to Portugal, which may be said to have been then at the height of its commercial greatness.

In the course of the 16th century many circumstances occurred which contributed greatly to the extension of commerce. The English in the pursuit of a north-west passage to India had discovered the whole coast of North America, where, after some years, they began to attempt settlements. They engaged in the Newfoundland fishery, and also in the whale fishery at Spitsbergen or Greenland. The continual jealousies and disputes between the English merchants and the German Hanseatic merchants of the Steel-yard in London, were at length terminated by the abolition of the peculiar privileges of the latter. The discovery of a passage to Russia round the north Cape of Lapland, opened a field for other new discoveries, and new branches of commerce; in consequence of which a company for trading to Russia was immediately formed and incorporated. The commerce with Turkey was encouraged by the incorporation of a company; and the intercourse with Guinea and other places on the coast of Africa, was also thought of sufficient importance to have a company established for carrying it on.

While the importance of the Italian cities was declining, and the commerce of the towns on the Baltic experiencing some diminution, the cities of Hamburgh and Antwerp had risen into considerable importance. The latter in particular, from the convenience of its situation, might for some time be considered as the centre of the commerce of Europe, as well for the merchandize of both the Indies, as for the naval stores and other bulky commodities of the northern states. It was however soon to find a rival among its industrious neighbours in the United Provinces, who, from the time of their independence, applied themselves to manufactures and commerce with the utmost assiduity. France was at this time beginning to encourage the cultivation of the vine, and the improvement of her broad silk manufacture; while Spain, by expelling the protestants from the Netherlands, supplied England, Holland, and the Hanse-towns with great numbers of wealthy and industrious manufacturers and artificers, as well as with an accession of many ingenious and beneficial new manufactures.

The 17th century was the period in which the principles were adopted, and most of the establishments formed, which have contributed to advance the commerce of Europe to its present astonishing height. The interests of nations became better understood than in any former age; the utility of commerce had become evident to every one, from the wealth and power it had conferred on the states which had encouraged it; and commercial treaties became frequent between the different nations. Navigation was improved; new settlements were formed, and many of those before made were rising into importance; manufactures were advancing in many parts of Europe; shipping was increasing, and the intercourse between distant places, from the accumulation of knowledge and experience, becoming more expeditious and secure.

The lucrative commerce of the East became one of the leading objects of mercantile pursuit. An English East India company was formed in 1600; and the Dutch companies, which were united in 1602, became one of the most celebrated commercial establishments ever formed. The French visited the East Indies in 1601, but did not establish a regular company for carrying on the trade till 1664. The Danes established an East India company in 1617, and in 1627 the king of Sweden issued letters patent for forming an East India company, but it was not carried into execution till some years after. The Spaniards and Portuguese, however, at this period, possessed by far the greatest share of the commerce of India, which had now become very considerable. The following account published by Mr. Munn, in 1621, of the quantity of Indian merchandize consumed annually in Europe, gives a very good idea of the proportion of the different articles of this branch of commerce: the prices affixed are the prime cost in India, including all charges till actually shipped for Europe.

	s.	d.	
6,000,000 lb. pepper, at	0	2½	per lb.
450,000 lb. cloves, at	0	9	per lb.
150,000 lb. mace, at	0	8	per lb.
400,000 lb. nutmegs, at	0	4	per lb.
350,000 lb. indigo, at	1	2	per lb.
1,000,000 lb. raw silk, at	8	0	per lb.

This statement was probably meant to include only the principal articles; at least it is certain that about 1631 several other kinds of merchandize were usually imported from India, as taffaties, painted callicoes, drugs of various sorts, and China ware. Tea, the great object of commercial intercourse with China, was either not yet an object of commerce, or was imported in such small quantities, that in England at least, in 1660, it was not thought of sufficient consequence to be subjected to a duty.

Dr. Davenant, who published his "Discourses on Trade" in 1698, was of opinion, that from about the year 1656 to 1688, England had every year gradually increased in riches; and that about the last mentioned year, the increase or addition to the wealth, and general stock of the nation, arising from foreign trade and home manufactures, was at least two millions per annum. In this estimate the different branches of trade are stated as follows:

The plantation trade may bring in	-	£ 600,000
The East India trade may bring in	-	500,000
The European, African, and Levant trade, by our own product may bring in - -	-	600,000
Ditto, by re-exports of plantation goods - -	-	120,000
Ditto, by re-exports of East India goods - -	-	180,000
	Total	2,000,000

This account is probably somewhat beyond the truth, with respect to the period to which it refers; but that there had been a considerable influx of wealth, is shewn by the observations of the same author, that from the year 1600 to 1688, the general rental of England was nearly trebled, and the purchase of land half doubled; that the stock of the kingdom was multiplied above five fold, and the money in circulation above four fold. This rapid advance in wealth, can be ascribed to no other cause than the improvement of commerce, which was now becoming of the utmost importance to all the European states, particularly to such as were desirous of maintaining any degree of naval power.

The increase of wealth arising from the extension of commerce, gave rise to the establishment of banks, by which its operations have of late years been so much facilitated. The commercial cities of Venice and Genoa had long experienced the utility of such institutions, which were now adopted in other states. The banks of Amsterdam, of

Hamburgh, and of Rotterdam were eſtabliſhed; and in 1694, the bank of England, and the bank of Scotland. The buſineſs of private bankers likewiſe took its riſe, and had become conſiderable, when it received a ſevere check from the unjuſtifiable conduct of Charles II. in ſeizing the money which the bankers had advanced on credit of the taxes. This branch of mercantile intercourſe has however been ſince carried to an extent which in former times would have been deemed wholly incredible.

Thus, with its principles generally underſtood; with moſt of the eſtabliſhments formed which are neceſſary to facilitate its operations; with laws and treaties in force for its encouragement and protection; markets eſtabliſhed for the purchaſe or ſale of commodities in almoſt every part of the globe; navigation brought to a high degree of perfection, vaſt improvements in arts and manufactures; and a great increaſe of artificial wants from the progreſs of luxury and refinement; the commerce of the world, and particularly of Europe, has, during the 18th century, expanded in an aſtoniſhing degree, and become intimately connected with the political exiſtence of almoſt every ſtate.

COMMERCE *of Great Britain*. The moſt authentic materials from which an idea can be formed of the progreſs and extent of the commerce of Great Britain, are the accounts kept in the office of the inſpector-general of exports and imports, at the cuſtom-houſe of London. Theſe accounts do not ſhew the current value of the commodities exported or imported, but are formed from their quantities, according to certain rates of value affixed to the ſeveral articles of foreign trade in 1696, by which they have been rated ever ſince. It is evident, therefore, that, as the price of all kinds of merchandize is ſubject to great fluctuations, and in general has much increaſed in this country within the laſt hundred years, theſe accounts are far from ſhewing the actual values in the later years; they are, however, from this very circumſtance of being uniformly made up at the ſame rates, the better adapted to a comparative view, and ſhew a progreſſive increaſe which has arrived to an amount never before known in the commerce of any nation. According to theſe eſtimates the total amount of the exports and imports of Great Britain have been as follows:

Years.	Imports.	Exports.
1700	£5,970,175	£7,302,716
1701	5,869,606	7,621,053
1702	4,159,304	5,235,874
1703	4,526,596	6,644,103
1704	5,383,200	6,552,019
1705	4,031,649	5,501,677
1706	4,113,933	6,512,086
1707	4,274,055	6,767,178
1708	4,698,663	6,969,089
1709	4,510,593	6,627,045
1710	4,011,341	6,690,828
1711	4,685,785	6,447,170
1712	4,454,682	7,468,857

At the concluſion of the war, by the peace of Utrecht, a commercial treaty with France was likewiſe negociated: but when the particulars of it came to be diſcuſſed, two of the articles, by which the produce and manufactures of France were to be admitted into this country on the ſame terms as thoſe of the moſt favoured nation, excited ſuch general diſapprobation, that the bill for carrying it into effect was rejected by the houſe of commons. The ſtrongeſt objection to the principle of the treaty, was that it might ruin the trade then carried on with Portugal, which was conſidered as the moſt valuable branch of our European commerce.

It is evident, that from the year 1705, notwithſtanding the diſadvantages it always labours under in time of war, commerce had been gradually increaſing; but when peace enabled it to return to its uſual channels, and reſtored ſome branches which had been conſiderably interrupted, its general advancement became more obvious, and although from the mode then uſually adopted, of judging of the profits of commerce merely by the exceſs of the value of the exports, the balance appeared leſs than it had been in former years, the wealth which flowed into the country from foreign trade, being no longer abſorbed in public loans, ſoon enabled the government to make a permanent reduction in the legal rate of intereſt. The war with Spain in 1718, did not cauſe much interruption of commercial intercourſe, except in the direct trade with that country.

Years.	Imports.	Exports.
1713	£5,811,077	£7,352,655
1714	5,929,227	8,361,638
1715	5,640,943	7,379,409
1716	5,800,258	7,614,085
1717	6,346,768	9,147,700
1718	6,669,390	8,255,302
1719	5,367,499	7,709,528
1720	6,090,083	7,936,728
1721	5,768,510	8,681,200

At this period the judicious principle of promoting the exportation of Britiſh manufactures, which had hitherto been applied only to woollen goods, was extended to Britiſh manufactures and produce in general; which were allowed to be exported duty free, except a few articles chiefly materials for manufactures, the exportation of which it would not have been proper to encourage; while drugs and other materials uſed for dyeing, were, upon being firſt duly entered, to be imported duty free, but upon re-exportation were to pay ſpecific duties. For this highly beneficial regulation, ſo ſimple in its principle, and ſo comprehenſive in its extent, the country was indebted to the enlightened wiſdom of Mr. Walpole: the experiment excited much doubt and ſolicitude as to its ſucceſs, but it ſoon appeared that the loſs of revenue in the duties thus given up, was a mere trifle in compariſon with the ſtimulus it gave to manufactures and the conſequent extenſion of commerce.

Years.	Imports.	Exports.
1722	£6,378,098	£9,650,789
1723	6,505,676	9,489,811
1724	7,394,405	9,143,356
1725	7,094,708	11,352,480
1726	6,677,865	9,406,731
1727	6,798,908	9,553,043
1728	7,569,299	11,631,383
1729	7,540,620	11,475,771
1730	7,780,019	11,974,135
1731	6,991,500	11,167,380
1732	7,087,914	11,786,658
1733	8,016,814	11,777,306
1734	7,095,861	11,000,645
1735	8,160,184	13,544,144
1736	7,307,966	11,616,356
1737	7,073,638	11,842,320
1738	7,438,960	12,289,495

The above period was almoſt wholly a time of peace, during which the commerce of Great Britain was gradually

advancing, both from the improvement of feveral of the exifting branches, and the acquifition of new ones. The South-fea company undertook the Greenland whale fifhery, which had been entirely relinquifhed by this country for fome years paft; and encouragement was given to fifheries on the coaft of America. Attempts were made to obtain a fhare of the fur trade of north America, which was almoft entirely in the hands of the French. The Oftend Eaft India company, which had been found prejudicial to the Englifh trade in thofe parts, was fufpended; while our trade with China increafed confiderably, particularly in the article of tea. The trade of the Levant company was very flourifhing; as was likewife that of the Hudfon's bay company, though the latter was but of fmall extent. The produce of feveral valuable commodities was at the fame time augmenting, from an increafed cultivation of rice in the American colonies, and of coffee in the Weft India iflands, while great quantities of corn were annually exported from Great Britain to France, Portugal, Spain, and Italy.

The war which began in 1739, was occafioned chiefly by difputes refpecting our commerce in the Weft Indies, which had been much interrupted by the Spaniards. It caufed, at firft, fome decline of foreign trade, which however foon regained the extent to which it had been carried during the preceding peace.

Years.	Imports.	Exports.
1739	£7,829,373	£9,495,366
1740	6,703,778	8,869,939
1741	7,936,084	11,469,872
1742	6,866,864	11,584,427
1743	7,802,353	14,623,653
1744	6,362,971	11,429,628
1745	7,847,123	10,497,329
1746	6,205,687	11,360,792
1747	7,116,757	11,442,049
1748	8,136,408	12,351,433

At this time, a much greater proportion of the exports confifted of unmanufactured produce than it has fince; as it appears there had been exported from England in five years, from 1744 to 1748, no lefs than 3,768,444 quarters of corn, which at medium prices was worth 8,007,948 *l.*

That a confiderable increafe of commerce had taken place, is evident from the quantity of fhipping employed. The total tonnage of veffels that cleared outwards on an average of three years preceding the war, had been 503,568 tons; the average of the three years, ending with 1751, was 661,184 tons. The encouragement of the fifheries, and the regulation of the Guinea or African trade, which had been in the hands of an exclufive company, but was now in a great meafure laid open; caufed fome extenfion of foreign trade, although the Levant, or Turkey trade, which had been confidered as one of the moft valuable branches, was beginning to decline rapidly, from the French improving the natural advantages they poffefs for a trade with thofe parts.

Years.	Imports.	Exports.
1749	£7,917,804	£14,099,366
1750	7,772,039	15,132,004
1751	7,943,436	13,967,811
1752	7,889,369	13,221,116
1753	8,625,029	14,264,614
1754	8,093,472	13,396,853
1755	8,772,865	12,182,255
1756	7,961,603	12,517,640
1757	9,253,327	13,438,285
1758	8,415,025	15,034,994
1759	8,922,976	14,696,892
1760	9,832,802	15,579,073
1761	9,543,901	16,365,953
1762	8,870,234	14,134,093

It is evident that commerce had not been very materially affected by the war. The years 1755 and 1756 marked the loweft point of its depreffion; whence it gradually rofe, till it had gained a fuperiority over the unexampled traffic of 1750, a year of eftablifhed peace and fecurity.

By the peace of 1763, although many iflands which had been taken in the Weft Indies were reftored, Great Britain retained a number of newly acquired iflands, perhaps more than could be immediately brought into cultivation with advantage. The arrangements refpecting Afia were very favourable to the Eaft India company, and in Africa an exclufive trade was fecured in the article of gum Senegal, a material indifpenfably neceffary to the perfection of many of our manufactures. The immediate confequence, however, of the acquifition of additional territories, was, that a wide field was opened for fpeculation and commercial enterprife, which caufed much productive capital to be withdrawn from the trade and manufactures of Great Britain; yet our merchants were not only able to maintain their own credit, but alfo to affift their correfpondents during the commercial embarraffments in Holland and other parts of the continent.

In 1765, the principles and meafures were adopted which foon involved the country in difputes with its American colonies. Impolitic reftrictions were laid on a beneficial intercourfe which had long fubfifted between the Britifh colonies and the Spanifh Weft India fettlements; which being foon followed by other caufes of difcontent, drove the Americans into public refolutions to make no further importations from Great Britain, but fuch as were unavoidably neceffary, and to encourage, to the utmoft of their power, every kind of manufacture that was practicable among themfelves. This ftep foon produced ferious effects in Great Britain; the merchants connected with America found themfelves unable to fulfil their engagements by the ftoppage of large fums due to them from that country; the whole fyftem of their bufinefs was deranged, and general diftrefs fpread through the circle of their connections; the manufacturers fuffered by the want of regular payments from the merchants, while their materials, and made up goods, to an alarming amount, were becoming a dead ftock upon their hands; in confequence of which, great numbers of workmen were thrown out of employ. Petitions were prefented to parliament from all the trading and manufacturing towns, which probably had fome effect in procuring a temporary adjuftment of the difpute.

The non importation agreement in America, was renewed in 1769 and 1770; yet the commerce of Great Britain, notwithftanding thefe interruptions of an important branch of it, continued to increafe; and previous to the war which followed, had attained to a greater extent than in any former years.

Years.	Imports.	Exports.
1763	£11,665,036	£16,160,181
1764	10,364,307	16,512,403
1765	10,889,742	14,550,507
1766	11,475,775	14,024,964
1767	12,073,956	13,844,511
1768	11,878,661	15,117,982
1769	11,908,560	13,438,236

Years.	Imports.	Exports.
1770	12,216,937	14,266,653
1771	12,821,995	17,161,146
1772	14,508,715	18,732,379
1773	12,522,643	16,654,052
1774	14,548,902	17,607,447

The prohibition of all trade and intercourfe with the American colonies excited ferious alarms, not only on account of the lofs of a valuable branch of trade, but from the fuppofed encouragement which the acquifition of it would give to the trade of thofe powers who affifted the colonies. Thefe apprehenfions, however, in a few years appeared to be in a great meafure groundlefs, many Britifh manufactures found their way to America, though not imported directly from hence; and Mr. Chalmers obferves, that "there was an evident tendency in our traffic to rife in 1779, till the Spanifh war impofed an additional burthen. There was a fimilar tendency in 1780, till the Dutch war added, in 1781, no inconfiderable weight. And the year 1781, accordingly, marks the loweft degree of depreffion, both of our navigation and our commerce, during the war of our colonies. But with the fame vigorous fpirit, they both equally rofe, in 1782, as they had rifen in former wars, to a fuperiority over our navigation and commerce, during the year wherein hoftilities with France began."

Years.	Imports.	Exports.
1775	£ 14,816,955	£ 16,946,523
1776	12,449,189	15,685,107
1777	12,643,834	14,152,243
1778	10,975,533	12,375,712
1779	11,435,263	13,597,771
1780	11,714,967	13,689,073
1781	12,723,613	11,470,388
1782	10,341,628	13,224,637

The opportunity of renewing the commercial connections between this country and America, from the conclufion of peace, was eagerly embraced; but fubfequent experience proved, that a greater degree of caution had now become neceffary to render it a beneficial trade. The arrangements relative to the commerce of Ireland, had a very beneficial effect in that country, which had hitherto been excluded from almoft every fpecies of commerce, and reftrained from fending the produce of her own foil to foreign markets. The convention with Spain fettled more accurately the limits within which Britifh fubjects were allowed to cut logwood on the Mufquito coaft, and confequently gave greater certainty and fecurity to the trade with thofe parts. The commercial treaty with France, by difcontinuing many of the prohibitions and prohibitory duties which had exifted for almoft a century between the two nations, opened a wide field for fpeculation and adventure. The confolidation of the cuftoms by the abolition of all the confufed and complex duties which then exifted, and the fubftitution of a fingle duty on each article in their ftead, was a meafure of great convenience to all perfons engaged in mercantile tranfactions. Under all thefe circumftances, fupported by the improvements which had taken place in feveral of the principal manufactures, the foreign trade of Great Britain increafed greatly during the peace, and in the year 1792, had attained to an unparallelled height, both in point of value, and with refpect to quantity of fhipping employed in it.

Years.	Imports.	Exports.
1783	£ 13,122,235	£ 15,450,778
1784	15,272,802	14,961,074
1785	16,279,490	16,770,239
1786	15,786,072	16,300,730
1787	17,804,024	16,870,114
1788	18,027,170	17,472,408
1789	17,821,102	19,340,548
1790	19,130,886	20,120,121
1791	19,669,782	22,731,995
1792	19,659,358	24,905,200

The total number of veffels which belonged to the feveral ports of the Britifh empire on the 30th September 1792, was 16,079; the amount of their tonnage 1,540,145 tons; and the number of men and boys ufually employed in navigating them 118,286. The number of veffels that entered inwards at the feveral ports of Great Britain (including their repeated voyages) was as follows:

	Ships.	Tons.
Britifh - - -	12,030	1,587,645
Foreign - - -	2,477	304,074
Total	14,507	1,891,719

At this period, the commerce of Great Britain was generally admitted to be in a very flourifhing ftate. The application and improvement of machinery in almoft every branch of manufacture, had reduced the charges of workmanfhip fo far, as to enable our manufacturers to fupply foreign markets on better terms than any other country could offer; while the increafe of capital, arifing from the accumulation of the profits of fuccefsful commerce during a period of peace, gave our merchants the means of allowing longer credit than could be obtained elfewhere. The high price of the public funds, led many perfons to employ their money in difcounting private fecurities, which greatly facilitated the extenfion of commercial credit, but probably tempted fome to trade much beyond the amount which their capital juftified, or to fpeculate largely without any real property of their own; fo that when the apprehenfion of war produced a greater degree of caution, and began to affect particular branches of trade, many were involved in embarraffments; and on the commencement of the war in 1793, commercial concerns, in general, experienced a ferious fhock. The affiftance afforded by government to fuch houfes as appeared to be really folvent, by lending them exchequer bills for a certain time, operated very fuccefsfully, and averted the confequences that were apprehended; credit revived, and as the war in its progrefs almoft annihilated the foreign trade of fome of the powers engaged in it, the commerce of Great Britain received a confiderable augmentation; and, protected by its naval fuperiority, continued to increafe, notwithftanding all the meafures which political animofity could devife to obftruct or deftroy it.

Years.	Imports.	Exports.
1793	£ 19,256,717	£ 20,390,180
1794	22,288,894	26,748,967
1795	22,736,889	27,312,338
1796	23,187,319	30,424,184
1797	21,013,956	28,917,010
1798	27,857,889	33,591,777
1799	26,837,432	35,991,329

Years.	Imports.	Exports.
1800	30,570,605	43,152,019
1801	32,795,557	42,301,701

The increase during the above period, though really very great, was not however equal to what it would appear from the above accounts to have been. This irregularity in the comparative view which the account of imports and exports generally furnishes with sufficient accuracy, of the commerce of Great Britain, arises from the article of coffee, the import of which was formerly little more than sufficient to supply its small consumption in this country. But the interruption of the trade of France, the conquest of their West India islands, and the greatly increased cultivation of coffee in Jamaica, caused nearly the whole supply of the continent with this commodity to depend during the war on Great Britain. In the inspector-general's book of rates, coffee is valued on importation at 7 *l.*, and on exportation, at no less than 14 *l.* 10 *s.* per cwt.; while, during the above period, the real average value was about 5 *l.* per cwt. when imported, and 5 *l.* 10 *s.* when exported. The official account, therefore, from 1794, when coffee suddenly became a very considerable article of exportation, requires some correction; and if the over-estimated value of this article is deducted, the exports of the year 1800 will appear to have been 38,120,120 *l.*, and of 1801, 37,786,856 *l.*

The short interval of peace in 1802, produced an immediate extension of foreign trade; and Mr. Addington thought himself justified "in pronouncing the commerce of the country to be in a state of unrivalled and unexampled prosperity." The value of British manufactures exported, considerably exceeded the preceding year, and the total amount of the exports, according to the official values, was 46,120,962 *l.* But in this and the succeeding years, it will be proper to adopt the correction just mentioned, which will give the amount of the imports and exports as follows:

Years.	Imports.	Exports.
1802	£31,442,318	£41,411,966
1803	27,992,464	31,578,495
1804	29,201,490	34,451,367
1805	30,344,628	34,954,845
1806	31,094,089	36,528,132

The account of imports for the last year is not quite correct; the imports from the East Indies for that year being incomplete.

Almost every article being greatly under-valued in these accounts (except in one or two instances) the total must give a very inadequate idea of the real extent of the commerce of Great Britain. Some idea may be formed of the undervaluation of the imports by those of the East India company, taking the account of their sales as the importation; the medium value of which, on an average of three years, was 6,100,000*l.*; whereas, the medium value by the accounts of the inspector-general, for the same three years, was 4,572,000*l.* Of the actual value of British produce and manufactures exported, which usually constitutes about two-thirds of the total export, we have more correct information. By an act passed in 1798, and revived in 1802, called the convoy act, the exporters were required to declare the real value of British manufactures exported, in order to ascertain the amount of duty chargeable thereon; and from these declarations, the actual value of British produce and manufactures exported has been ascertained as follows:

In 1803	£40,100,870
1804	40,349,642
1805	41,068,942
1806	43,242,176

The extent of shipping employed in commercial intercourse at this period, will be seen in the following account of the number of vessels which belonged to the several ports of the British empire, on the 30th September 1805.

	Ships.	Tons.	Men & Boys
England - - -	14,790	1,799,210	117,668
Jersey & Guernsey	185	16,528	2,011
Isle of Man - -	404	9,050	2,336
Scotland - - -	2,581	210,295	15,160
Ireland - - - -	1,067	56,806	5,070
The Plantations -	3,024	190,953	15,407
	22,051	2,283,442	157,712

The commerce of Great Britain with *Ireland*, has increased with the improvement of that country, particularly since the year 1780, when a more liberal system of policy was adopted with respect to the foreign trade of Ireland. The imports from thence consist chiefly of butter, beef, pork, bacon, lard, tallow, cattle, hides, feathers, starch, rape-seed, linens, linen-yarn, woollen-yarn, pearl-ashes, copper-ore, and a few other articles of less importance. The exports are coals, ironmongery and hardware, hoops for barrels, beer, cyder, dried cod, herrings, chiefly from Scotland, earthenware, bottles and window-glass, refined sugar, hops, lead, tin-plates, sail-cloth, cabinet-ware, wearing apparel, apothecaries-ware, books and stationary, painters' colours, hats, haberdashery, woollen, cotton, and silk manufactures of all kinds; with rum, brandy, geneva, wines, groceries, drugs, dye-stuffs, flax and hemp, raw and thrown silks, and other foreign produce.

Years.	Imports.	Exports.
1798	£2,735,686	£2,974,363
1799	2,770,731	4,086,986
1800	2,312,824	3,741,499

Considerable endeavours have been made to improve the manufactures of Ireland, but with little success, except in the linen manufacture, which probably proceeds from the want of sufficient capital, and from the facility with which British manufactures can be procured at a very small additional expence; the latter will, therefore, for a long time, continue to constitute a large proportion of the imports of Ireland.

Value of British manufactures exported from Great Britain to Ireland.

In 1791	£1,470,972	In 1796	£1,781,789
1792	1,511,844	1797	1,310,996
1793	1,055,276	1798	1,657,954
1794	1,281,316	1799	2,405,999
1795	1,612,270	1800	1,787,966

The trade between Great Britain and *Russia* has been considered highly beneficial to both countries; to Russia in point of profit, and to Great Britain, as supplying articles essential to the support of its navy. The capital employed must be much greater than formerly, from the increased value of the principal articles; and the balance of trade, which is consider-

ably in favour of Ruſſia, is paid by means of the commercial tranſactions between Great Britain and other countries. The articles imported are iron, hemp, flax, tallow, pot-aſhes, deals, and lath-wood, coarſe linens, hog's briſtles, &c. The exports are principally broad-cloths and woollen ſtuffs, refined ſugar, cotton, lead, tin, iron and ſteel ware, earthen ware and glaſs, coals, alum, ſalt, horſes, London porter, with articles of leſs importance.

Years.	Imports.	Exports.
1800	£ 2,382,098	£ 1,025,335
1801	2,246,877	919,843
1802	2,182,430	1,376,399

The total number of veſſels that entered inwards from Ruſſia, and that cleared out for that country from Great Britain in three years, ending with 1806, was as follows:

	Inwards.		Outwards.	
Years.	Britiſh.	Foreign.	Britiſh.	Foreign.
1804	830	29	558	53
1805	961	14	927	52
1806	1106	21	677	32

The trade to *Denmark* and *Norway*, though of ancient date, is not of very great extent; the imports conſiſt chiefly of timber and corn; and the exports, of Weſt India produce and other foreign merchandize; the quantity of Britiſh manufactured goods which thoſe countries take being of ſmall amount.

Years.	Imports.	Exports.
1800	£ 241,563	£ 540,698
1801	208,794	416,475
1802	155,672	537,517

The total number of veſſels which entered inwards from Denmark and Norway, in the year 1806, was 1607, of which 529 were Britiſh ſhips: the total number which cleared outwards was 1690, of which 790 were Britiſh.

The trade with *Sweden*, which is carried on chiefly in ſhips of that country, has not varied materially in its extent during the laſt twenty years. The imports conſiſt chiefly of iron of a ſuperior quality, pitch, tar, deal boards, and ſail-cloth. The exports are principally colonial produce.

Years.	Imports.	Exports.
1800	£ 309,280	£ 78,840
1801	295,645	111,254
1802	327,350	108,296
1803	288,651	98,045

The total number of veſſels which entered inwards from Sweden, in the year 1806, was 353, of which 187 were Britiſh ſhips: the total number which cleared outwards was 362, of which 142 were Britiſh.

The imports from *Pruſſia*, conſiſt of all kinds of grain, hemp, flax, madder, linſeed, gooſe-quills, briſtles, pearl-aſhes, mill-ſtones, and timber of various deſcriptions. The exports are chiefly alum, copperas, coals, beer, ſalt, wrought braſs and iron, lead, tin plates, earthen-ware, glaſs, woollen and cotton goods, ſome cotton yarn, India goods, raw and refined ſugar, drugs, dye-ſtuffs, pepper and other ſpices, coffee, rum, tobacco, &c.

Years.	Imports.	Exports.
1800	£ 1,340,904	£ 794,452
1801	1,387,149	660,739
1802	1,057,602	1,071,896
1803	831,225	1,916,502

The total number of veſſels which entered inwards from Pruſſia in the year 1805 was 1946, of which 837 were Britiſh ſhips: the total number which cleared outwards was 1627, of which only 482 were Britiſh. In 1806 the total numbers were much leſs, in conſequence of Pruſſia being involved in the war.

The trade with *Germany* had not experienced any conſiderable variation with reſpect to its extent, from the commencement of the laſt century, till on the extenſion of the war with France in 1794, it ſuddenly became the channel through which the principal part of the continent received the goods they had before obtained direct from Great Britain. The following account of exports to Germany ſhews the rapid increaſe of trade with that country during the war.

Years.	Britiſh Manufactures.	Foreign Merchandize
1793	£ 718,474	£ 1,764,221
1794	1,634,530	4,308,695
1795	1,760,133	6,311,876
1796	1,591,810	6,582,179
1797	1,964,967	6,419,587
1798	2,042,774	8,646,691
1799	2,032,567	6,640,729
1800	4,364,120	8,300,470
1801	4,928,617	6,186,687

The total number of veſſels which entered inwards in the ſeveral ports of Great Britain from Germany (including Hamburgh) and which cleared outwards for that country, was as follows:

	Inwards.		Outwards.	
Years.	Britiſh.	Foreign.	Britiſh.	Foreign.
1793	217	54	292	77
1794	258	108	443	152
1795	259	222	257	406
1796	347	342	333	415
1797	237	257	314	371
1798	408	113	647	187
1799	409	126	426	181
1800	435	459	574	458

The total number of veſſels which entered inwards from Germany (including Hamburgh) in the year 1806 was 604; the total number which cleared outwards for that country 956.

The imports from *Holland* are butter and cheeſe in large quantities, geneva, juniper berries, flax, hemp, oak bark, rags, flower-roots and ſeeds, books, maps and prints. The exports are raw and refined ſugars, train oil, copperas, a few cotton goods, ſome woollen goods, coffee, rice, and foreign merchandize of various kinds: their amount, as follows:

Years.	Imports.	Exports.
1800	£ 972,600	£ 3,208,613
1801	1,025,958	3,496,744
1802	974,537	4,957,997
1803	630,403	1,565,355

The total number of veſſels which entered inwards from Holland in the year 1804 was 790, and the number which cleared outwards 521. The number which entered inwards in 1805, was 709; outwards 323; which, from the two countries being at war, were of courſe nearly all neutral veſſels.

France poſſeſſes ſuch natural advantages in the produce of its ſoil, and the convenience of its ſituation for procuring the commodities of all other countries, that while its manufac-

tures were encouraged, and it retained poſſeſſions in the Eaſt and Weſt Indies, little inducement remained for commercial intercourſe with Great Britain, and even this limited traffic was much impeded by the high duties and prohibitions which mutual jealouſy had impoſed. In 1786 a more liberal ſyſtem was adopted by a treaty of commerce, in conſequence of which the trade between the two countries increaſed conſiderably. In the year 1792, the exports to France amounted to 1,228,166*l.* 3*s.* 9*d.* of which 743,280*l.* 12*s.* 1*d.* was Britiſh manufactures, and 484,885*l.* 11*s.* 8*d.* foreign merchandize. In the following year, the trade with France was ſuſpended by war, on the termination of which, in 1802, commiſſioners were appointed for adjuſting the conditions of a new commercial treaty, but its completion was prevented by the renewal of hoſtilities.

The trade with *Portugal* was formerly a very beneficial branch of our commerce, but has declined very much. The imports conſiſt chiefly of wine, cotton-wool, and indigo, with conſiderable ſums in caſh and bullion. The exports are almoſt wholly Britiſh produce and manufactures.

Years.	Imports.	Exports.
1798	£ 700,383	£ 750,918
1799	1,047,054	1,073,411
1800	916,848	1,011,893

The total number of veſſels which entered inwards from Portugal in the year 1800 was 340, of which 270 were Britiſh veſſels. The number which entered inwards in the year 1806 was 468; outwards 332.

The extent of the trade with *Spain*, previous to the war in 1796, will appear from the ſtatement of imports and exports.

Years.	Imports.	Exports.
1792	£ 897,840	£ 794,101
1793	485,872	476,726
1794	748,546	634,554
1795	992,853	437,830
1796	809,881	546,126

The year 1806 being a year of war, the trade with Spain was of courſe confined to neutral veſſels: the number which entered inwards was 222, and the number which cleared outwards 126.

The *Mediterranean trade* was ſubject to much interruption during the war which began in 1793, in conſequence of which many of the goods uſually imported from Venice and Italy were brought over-land through Switzerland and Germany to Hamburgh and Tonningen to be ſhipped for England. The Turkey and Levant trade was formerly one of the principal branches of Engliſh commerce, but it is now of much leſs importance. The chief articles imported, are cotton-wool, mohair, goats' hair, opium, ſenna, and other drugs, galls, madder, vallonea, and other dye-ſtuffs, currants, figs, raiſins, goat ſkins, and box-wood; raw ſilk was formerly a principal article, but very little is now brought from Turkey, that of Italy being much ſuperior. The exports conſiſt of lead, tin-plates, wrought and caſt iron, hardware, a conſiderable number of watches, ſome cotton goods, and a few woollen goods, India piece goods, coffee, ſugar, cinnamon, cloves, pimento and other ſpices. The extent of the different branches of the Mediterranean trade will appear from the following ſtatements.

GIBRALTAR and the STREIGHTS.

Years.	Imports.	Exports.	Ships inward.	Ships outward.
1799	£ 62,992	£ 358,784	47	50
1800	35,665	294,558	20	43
1801	24,887	362,971	19	54
1802	21,792	530,537	32	48
1803	23,112	487,699	17	48
1804	33,860	560,399	27	62
1805	42,919	183,824	19	59

In the year 1806, the number of veſſels which entered inwards was 24, outwards 83.

ITALY.

Years.	Imports.	Exports.	Ships inward.	Ships outward.
1799	£ 224,607	£ 367,173	69	81
1800	411,765	587,530	115	113
1801	165,042	378,007	44	94
1802	804,329	2,048,784	127	248
1803	748,020	656,607	182	74
1804	268,029	359,854	76	126
1805	393,517	507,535	106	117

In the year 1806, the number of veſſels which entered inwards was 90, outwards 61.

MALTA.

Years.	Imports.	Exports.	Ships inward.	Ships outward.
1801	£ 11,448	£ 88,735	10	14
1802	16,698	12,023	36	4
1803	8,922	133,629	22	15
1804	32,913	114,031	20	23
1805	9,304	127,515	6	12

In the year 1806, the number of veſſels which entered inwards was 26, outwards 26.

MINORCA.

Years.	Imports.	Exports.	Ships inward.	Ships outward.
1800	£ 13,500	£ 12,246	19	5
1801	6,768	36,130	16	15
1802	22,106	21,478	25	5

In the year 1803, the trade with Minorca ceaſed, from its having been reſtored to Spain.

TURKEY and LEVANT.

Years.	Imports.	Exports.	Ships inward.	Ships. outward.
1799	£ 33,091	£ 226,078	3	13
1800	199,773	166,804	19	6
1801	141,137	172,198	9	10
1802	182,424	180,000	20	18
1803	175,427	155,369	27	9
1804	148,277	81,625	16	1
1805	103,590	135,411	22	8

In the year 1806, the number of veſſels which entered inwards was 23, outwards 3.

The articles imported from the coaſt of *Africa* into Great Britain are gum arabic, gum ſandarach, and ſenegal, camwood, red-wood, ebony, ivory, a few oſtrich feathers, and ſome ſkins; their amount in the year 1800 was 82,289*l.* 8*s.* 8*d.* The exports have hitherto been of far greater value,

being principally intended for the purchase of slaves for the West Indies. They consisted of bugles, cowries, spiritous liquors, a great number of guns and cutlasses, gunpowder, wrought brass, copper and iron, glass, earthen ware, rice, groceries, apothecaries' ware, woollen, cotton, and linen goods, and large quantities of India piece goods. The total official value in the year 1800 was 1,017,365 *l.* 11 *s.* 5 *d.* of which 521,922 *l.* 19 *s.* 11 *d.* was British merchandize. The abolition of the infamous traffick in human beings, must cause a great revolution in the trade to this part of the world, as it appeared in the year 1789 that about 38,000 of the inhabitants of Africa were annually carried away in British ships for supplying the colonies with slaves, which of course employed a considerable number of vessels. The number of ships that cleared out from Great Britain for Africa, in the year 1804, was 176.

The *East India* trade furnishes a remarkable instance of an extensive branch of commerce carried on successively in the hands of an exclusive company, while most other commercial monopolies have made very small profits, and generally soon expired. The trade to India, however, since the immense territorial acquisitions of the English in that part, can no longer be considered as a mere commercial adventure, as it is now in a great measure a business of agency, for transmitting to Europe the fortunes acquired by British individuals in the East. The quantity of merchandize brought from thence, consequently greatly exceeds the value of the exports to India. The latter consists chiefly of woollens, metals, and naval and military stores, the remaining articles being of trifling amount in comparison, and almost wholly for the use of Europeans, as the natives are peculiarly attached to the use of their own produce and manufactures. The exports to China include a considerable amount in bullion, the other articles are woollen cloths and camblets, lead, and tin; the articles exported in private trade are, skins and furs, glass of various descriptions, jewellery, toys, and watches, cuttings of cloth, a very few woollens, some cutlery and hard ware, and silver. The amount of the company's exports to India and China, will appear from the following statements.

INDIA.

Season.	Merchandize, or Manufacture.	Metals.	Stores.
1781	£ 200,808	£ 157,614	£ 163,878
1782	123,834	183,356	133,773
1783	95,251	122,855	77,237
1784	92,205	93,806	55,256
1785	74,683	80,152	104,226
1786	122,709	97,899	85,179
1787	108,388	137,194	153,603
1788	119,449	99,028	152,587
1789	80,184	273,104	100,435
1790	75,141	191,944	120,525
1791	86,680	124,889	108,560

CHINA.

Season.	Merchandize, or Manufacture.	Metals.	Stores.	Bullion.
1781	£ 129,179	£ 10,349	£ 2,206	
1782	94,992	9,416	1,717	
1783	113,763	4,579	1,743	
1784	146,744	27,835	2,904	
1785	224,612	37,989	7,503	724,317
1786	202,023	35,535	6,972	749,833
1787	323,107	38,046	7,289	646,798
1788	335,392	59,208	6,598	489,192
1789	354,717	107,995	7,769	787,078
1790	431,385	105,707	4,081	532,705
1791	486,993	99,448	4,000	422,098

The imports from the East Indies consist of Bengal piece-goods, coast and Surat piece-goods, Bengal and China raw-silk, tea, pepper, saltpetre, nankeen cloth, china, wrought silks, a small quantity of china-ware, sugar, coffee, indigo, and various drugs. The total amount of the imports, on the company's account, and in private trade, according to the official rates of the inspector-general's office, was as follows:

Years.	Import.	Years.	Import.
1781	£ 2,526,339	1793	£ 3,499,023
1782	626,319	1794	4,458,475
1783	1,301,495	1795	5,760,810
1784	2,996,652	1796	3,372,689
1785	2,703,940	1797	3,942,384
1786	3,156,687	1798	7,626,930
1787	3,430,868	1799	4,284,805
1788	3,453,897	1800	4,942,275
1789	3,362,545	1801	5,424,441
1790	3,149,870	1802	5,794,906
1791	3,698,713	1803	6,348,887
1792	2,701,547	1804	5,214,621

But a more accurate idea of the real value of the imports from the East Indies, may be formed from the annual amount of the company's sales, which was

In 1801	£ 7,595,181	In 1803	£ 6,042,526
1802	6,626,347	1804	5,866,073

The *West India* trade is, in some respects, the most important branch of the commerce of Great Britain; as on the colonial produce which it supplies, much of the trade with different parts of Europe chiefly depends. The value of the British West India produce from the old islands, imported into Great Britain, on a medium of four years, preceding the 5th of January 1796, according to the current prices during that period, was estimated, exclusive of the duties, at about 6,800,000 *l.* per annum. This sum is not wholly a return for goods exported, a part of it must be considered as remittances of the property of persons who possess estates in the West Indies; but who are wholly or occasionally resident in England; and of persons who have lent money on mortgage or otherwise in the West Indies, and receive their interest from the sale of the produce.

Official Value of Imports from the West Indies.

Years.	British West Indies.	Conquered Islands.	Total.
1801	£ 6,759,617	£ 4,105,839	£ 10,865,456
1802	7,293,316	2,699,504	9,992,820
1803	5,786,432	362,014	6,148,436

The value of the British West India islands, in a commercial view, will be very conspicuous from the following statement of the total quantities of sugar, rum, coffee, and cotton-wool, exported from them.

Years.	Sugar. Cwt.	Rum. Galls.	Coffee. Cwt.	Cotton Wool. lbs.
1793	2,129 750	4,907.051	92,016	9 173,583
1794	2,141,921	5,597,520	141,007	8,473,175
1795	1,743,939	4,173,734	144,800	11,675,495
1796	1,816,584	5,567,754	94,086	8,854,413
1797	1,636,631	4,279,164	114,947	6,918,153
1798	2,015,602	6,224,076	165,075	7,909,832
1799	2,628 470	6,270,449	132,259	7,529,881
1800	2,413 997	6,231,225	180,374	10,611,349
1801	2,959,958	8,148,571	199,359	11,261,014
1802	3,463,366	8,676,381	230,148	8,799,891
1803	2,880,479	8,781,496	173,683	5,650,615

The total number of vessels which entered inwards from the West Indies, in the year 1804, was 721, containing 204,411 tons, and navigated by 12,119 seamen. The number of vessels which cleared outwards was 790. The value of British produce and manufactures exported to the British plantations in the West Indies, exclusive of the Conquered islands, was 3,408,232 *l.*

The trade with the United States of *America*, has rapidly advanced to very considerable importance; and Great Britain now supplies them with commodities to a far greater amount, than in the most favourable years previous to their independence, although the number of British ships employed is considerably less. In the year 1789 the number of British vessels which entered inwards in this trade was 253, the number outwards 358; in the year 1799, the number which entered inwards was only 42, the number outwards 57.

Years.	Imports.	Exports.
1798	£ 1,782 720	£ 5,580,370
1799	1,818 941	7,056 558
1800	2,357,922	6,885,507

The total number of vessels which entered inwards from the United States, in the year 1806, was 561, of which 53 were British; the total number which cleared outwards was 575, of which only 39 were British.

The remaining possessions of Britain in North America, being countries not very fertile or fully inhabited, the trade with them is not of very great extent. The following statement of the exports to those parts in the year 1800, will, however, shew that the trade is well worth preserving, independent of the consideration that it is the means of procuring articles of much importance in other branches of commerce.

To Hudsons bay	38.061	0	9
Newfoundland	219.458	5	11
Canada	460,155	13	3
New Brunswick	81,230	15	4
Nova Scotia	177,083	17	10
Total	£ 975,989	13	1

With respect to the general balance of trade, or the ultimate profit which Great Britain derives from its commerce with all other countries, Mr. Irving, the inspector-general of imports and exports, to whom the public have, for many years, been indebted for the judicious arrangement and explanation of the official documents relating to foreign trade, has justly remarked, that there are perhaps few questions to which the human attention can be directed more difficult to form an opinion upon, from the variety of considerations, and the vast statements with which it is connected, and also from the materials on which conclusions are to be formed, being in some instances defective; he has, however, stated it as his opinion, that the balance of trade in favour of Great Britain, according to the true value of the goods exported and imported, amounted on a medium of the four years preceding 1796, to upwards of 6,500,000 *l.* per annum, exclusive of the profits derived from the East and West India trades, which he estimated at upwards of 400,000 *l.* per annum; and exclusive of the profits derived from the fisheries.

An accurate view of the progress and extent of commerce in all the European states, would furnish much information; but with respect to several, no authentic particulars of this kind have been made public, and the foreign trade of others has been so entirely turned out of its usual channels since the commencement of the war of the French revolution, that any account of its present state would be very incomplete and unsatisfactory.

With respect to domestic commerce, we may observe, that the king is the arbiter of it; as it pertains to his prerogative to establish public marts, as markets and fairs, to regulate weights and measures, and to give money, which is the universal medium of commerce, authority and currency.

A great part of the foreign commerce of England is now carried on by collective companies: some incorporated by the king's charters, with an exclusive privilege, as the East India company; others only private associations, as the Turkey and Hamburgh companies. See Company.

Company

COMPANY, a collective term, underftood of feveral perfons affembled together in the fame place, or with the fame defign. See SOCIETY.

The word is formed of the French *compagnie,* and that of *companio* or *companies*, which, Chifflet obferves, are found in the Salic law, tit. 66. and are properly military words, underftood of foldiers, who, according to the modern phrafe, are comrades, or mefs-mates, i. e. lodge together, eat together, &c. of the Latin *cum*, *with*, and *panis*, *bread.* It may be added, that in fome Greek authors under the Weftern empire, the word *κυμπανα* occurs in the fenfe of *fociety*.

COMPANY, in *Commerce*, is an affociation of feveral merchants, or others, who unite in one common intereft, and contribute by their ftock, their counfel, and ftudy, to the fetting on foot, or fupporting, of fome lucrative eftablifhment.

Though *company* and fociety, or fellowfhip, be in effect, the fame thing, yet cuftom has made a difference between them; fociety, or partnerfhip, being underftood of two, or three dealers, or not many more; and *company* ufually of a greater number. See SOCIETY.

A fecond difference between *companies* and focieties is, that the firft, efpecially when they have exclufive privileges, cannot be eftablifhed without the conceffion of the prince; and need letters patent, charters, &c. Whereas, for the latter, the confent of the members, fixed and certified by acts and contracts, and authorized by bye-laws, is fufficent.

The feveral profeffions and trades exercifed in the city of London, being incorporated into diftinct fraternities, governed by their particular laws, a tabular view of them may not be unacceptable.

The abftract of their incorporations, and particular privileges, is taken from the records of the Tower, &c. and from the Firma-Burgi of Madox, the king's hiftoriographer; the account of their charities from thofe eminent hiftorians Stow and Strype; and the fines of the liverymen on admiffion, are taken from the returns to the clerk of the parliament, and the fcrutiny-books made after the feveral polls for the magiftrates and reprefentatives of the city.

The companies are here placed according to their prececedence, beginning with the twelve principal ones, of one or other of which the lord mayors have generally made themfelves free at their election, if they were not fo before; for they are not only the oldeft, but the richeft, many of them having had the honour of kings and princes to be their members, and the apartments of their halls being fit to entertain a monarch.

	Companies.	Halls.	Incorporated by	A. D.	Livery fines *l.*	*s.*	*d.*	Charitable Gifts paid yearly *l.*	and Privileges, &c.
1	Mercers	Cheapfide	Richard II.	1393	2	13		3000	Exclufive of 20 per cent. paid yearly to the widows of fubfcribing clergymen during life, pur-
2	Grocers	Poultry, Groc. alley	Edward III.	1345	20	0	0	700	fuant to a propofal accepted in
3	Drapers	Throgmorton ftreet	Henry VI.	1439	25	0	0	4000	1698, when they fettled a fund of
4	Fifhmongers	Thames-ftreet	Henry VIII.	1536	13	6	8	800	14,000*l.* a year for that purpofe.
5	Goldfmiths	Fofter-lane	Richard II.	1393	20	0	0	1000	They had a privilege from Ed. IV. to infpect, try, and regulate all gold and filver wares throughout the kingdom, and to punifh all workers in either that was adul-
6	Skinners	Dowgate-hill	Edward III.	1327	15	0	0	700	terated.
7	Merchant Taylors	Threadneedle-ftreet	Edward IV.	1466	20	0	0	2000	They were once ftyled taylors and linen armourers.
8	Haberdafhers	Maiden-lane	Henry VI.	1407	25	0	0	3500	Were anciently ftyled Milaners, becaufe they dealt in moft that
9	Salters	Swithin's-lane	Q. Elizabeth	1558	20	0	0	500	came from Milan.
10	Ironmongers	Fenchurch-ftreet	Edward IV.	1464	31	10	0	1800	In 1724, Mr Betton, a Turkey merchant, left 26,000*l.* in truft; one moiety of the profits of it to be always applied to the ranfom of Britifh captives from Moorifh flavery; the other for the poor of the company, and
11	Vintners	Thames-ftreet	Henry VI.	1437	31	13	4	600	to the charity-fchools in its city
12	Clothworkers	Mincing-lane	Edward IV.	1482	31	10	0	1400	and its liberty.

	Companies	Halls.	Incorporated by	A. D.	Livery fines	Charitable Gifts, paid yearly, and Privileges, &c.
					l. *s.* *d.*	*l.*
	Dyers	Elbow-lane	Edward IV.	1472	15 0 0	
14	Brewers	Addle ftreet	Henry VI.	1438	6 13 4	
15	Leatherfellers *	Little St. Helens	Henry VI.	1442	20 0 0	* Hen. VII. made their wardens infpectors of fheep, lamb, and calves leather throughout the kingdom.
16	Pewterers ‡	Lime-ftreet	Edward IV.	1474	20 0 0	‡ By act of Parl. 25 Hen. VIII. their wardens had the infpection of pewter throughout England.
17	Barber-furgeons †	Monkwell-ftreet	Edward IV.	1461	10 0 0	† In the reign of Hen. VIII. the furgeons of this company, then but 19, were exempted by parliament from ward and parifh offices, and from military fervice. They were incorporated feparately by 18 Geo. II. cap. 15. and the company of furgeons had an elegant hall in the Old Bailey, with a theatre for the diffection of human bodies. They now form a royal college, and their houfe is in Lincoln's Inn fields.
18	Cutlers	Cloak-lane	Henry V.	1417	10 0 0	
19	Bakers	Harp-lane	Edward II.	1307	10 0 0	
20	Wax-chandlers	Maiden lane	Richard III.	1483	5 0 0	
21	Tallow-chandlers	Dowgate-hill	Edward IV.	1463	15 0 0	
22	Armourers §	Coleman-ftreet	Henry VI.	1423	15 0 0	§ The brafiers are united to this company.
23	Girdlers ‖	Bafinghall-ftreet	Henry VI.	1449	5 0 0	‖ Q. Elizabeth incorporated the pinners and wire-drawers with them.
24	Butchers †	Pudding-lane	James I.	1615	11 11 0	† This is an ancient fraternity; of which we have an account in the reign of Henry II. A. D. 1180.
25	Sadlers	Cheapfide	Edward I.		10 0 0	
26	Carpenters	London-wall	Edward III.	1344	8 0 0	
27	Cordwainers	Diftaff-lane	Henry IV.	1410	10 0 0	
28	Painter-ftainers	Little Trinity-lane	Q. Elizabeth	1582	14 0 0	
29	Curriers	Near Cripplegate	James I.	1605	9 13 4	
30	Mafons	Bafinghall-ftreet	Charles II.	1677	5 0 0	
31	Plumbers	Near Dowgate-hill	James I.	1611	10 0 0	
32	Innholders	Elbow-lane	Henry VIII.	1515	10 0 0	
33	Founders **	Lothbury	James I.	1614	8 0 0	** All brafs weights made in London, or three miles from it, muft be fized with the company's ftandard, and have their mark; the averdupois to be fealed at Gu[illegible]hall, and the troy at goldfmith's hall. And the company are empowered by charter, to view and fearch all brafs weights, and brafs and copper wares made within the faid diftrict.
34	Poulters	No hall	Henry VII.	1504	10 0 0	
35	Cooks	Hall burnt	Edward IV.	1480	10 0 0	
36	Coopers	Bafinghall-ftreet	Henry VII.	1501	15 0 0	
37	Tylers and bricklayers	Leadenhall-ftreet	Q. Elizabeth	1568	12 0 0	
38	Bowyers	No hall	James I.	1620	8 0 0	
39	Fletchers ¶	St. Mary Axe	No charter		10 0 0	¶ It is only a company by prefcription.
40	Blackfmiths	Lambeth-hill	Q. Elizabeth	1577	8 0 0	
41	Joyners and cielers	Thames-ftreet	Q. Elizabeth	1569	8 0 0	
42	Weavers	Bafinghall-ftreet	Henry II.		6 0 0	
43	Woolmen	No hall	No charter		No livery; but they have a mafter, 2 wardens, and 11 affiftants. They are only a company by prefcription, yet fuppofed to have commenced with the wool-trade.	
44	Scriveners	No hall	James I.	1616	5 0 0	
45	Fruiterers	No hall	James I.	1605	5 0 0	
46	Plaifterers	Addle ftreet	Henry VII.	1501	8 0 0	
47	Stationers ††	Ludgate-ftreet	Philip & Mary	1557	20 0 0	†† This company, which alfo includes bookfellers, letter-founders, printers, and book-binders, have a ftock which is employed in printing almanacks, primers, pfalters, fchool-books, &c. of which they have the fole privilege, by virtue of a grant from the crown. This ftock confifts of fhares, which are diftributed in different proportions among thofe who have fined for, or ferved the office of renter-wardens: whofe fhares, if they die married, devolve to their widows. They pay above 200*l.* a year in penfions and other charities. They are likewife truftees for the difpofal of the confiderable legacies of Mr. William Bowyer, a learned printer, (who died Nov. 18. 1778) confifting of 30*l.* a year to the moft learned journeyman that can be met with; and 180*l.* a year in annuities of 20*l.* each to nine neceffitous printers of fixty-three years of age or upwards; befides other charities.
48	Broderers	Gutter-lane	Q. Elizabeth	1591	5 0 0	
49	Upholders	No hall	Charles I.	1627	4 10 0	
50	Muficians	No hall	James I.	1604	10 0 0	

	Companies.	Halls.	Incorporated by	A. D.	Livery fines. l. s. d.	Charitable Gifts, paid yearly, and Privileges, &c.
51	Turners	College-hill	James I.	1604	8 0 0	
52	Basket-makers	No hall	No charter		No livery; yet a company by prescription, governed by 2 wardens and 48 assistants, with this motto to its arms, *Let us love one another.*	
53	Glasiers ‖	No hall	Charles I.	1637	3 0 0	‖ The glass painters are incorporated with them.
54	Horners	No hall	Charles I.	1638	No livery; yet they have a master, 2 wardens, and 9 assistants, with a warehouse in Spitalfields; where they divide in lots, among themselves, such horns as are bought up by their members in Leadenhall and other markets: And in 1465, they obtained an act of parliament that none should be exported, but such as they refused.	
55	Farriers	No hall	Charles II.	1673	5 0 0	
56	Paviours	No hall	No charter		No livery; yet it is a fellowship by prescription, with 3 wardens, and 25 assistants.	
57	Loriners	London-wall	Q. Anne	1712	10 0 0	
58	Apothecaries	Blackfryars	James I.	1617	16 0 0	They are exempt from ward and parish-offices, and have a spacious physic-garden at Chelsea; which in 1721 was granted to the company for ever by Sir Hans Sloane, Bart. the lord of the manor, on condition of their paying a quit-rent of 5 *l.* and continuing it always as a physic-garden, and of presenting every year to the Royal Society fifty samples of different sorts of plants, there grown, till they amount to two thousand.—The latter of these conditions hath been long since more than completed. This is what may be called a trading company.
59	Shipwrights	No hall	James I.	1605	No livery; yet they have a master, 2 wardens, and 16 assistants.	
60	Spectacle-makers	No hall	Charles I.		No livery; yet have a master, 2 wardens, and 15 assistants.	
61	Clock-makers	No hall	Charles I.	1632	10 0 0	
62	Glovers	No hall	Charles I.	1638	5 17 4	
63	Comb-makers	No hall	Charles I.	1636	No livery; yet they have a master, 2 wardens, and 13 assistants.	
64	Felt-makers	No hall	James I.	1604	5 0 0	
65	Framework-knitters	Red cross-street	Charles II.	1663	10 0 0	
66	Silk-throwers	No hall	Charles I.	1630	No livery; yet have a master, 2 wardens, and 20 assistants.	
67	Silkmen	No hall	Charles I.	1631	No livery; yet have a governor, and 20 assistants.	
68	Carmen, have no hall, nor charter, nor livery; but are a fellowship by act of common council, with the title of Free Carmen of the city of London, and have a master, 2 wardens, and 41 assistants, under the direction of the lord mayor and aldermen. The carts that belong to this fellowship, which are betwixt 4 and 500, are, by an act of common council, subjected to the rule of the president and governors of Christ's Hospital; to whom the owner of every cart pays 17 *s.* 4 *d.* a year for a licence to work it, and every cart is brought to the hospital to have a number in brass put upon it.					
69	Pin-makers	No hall	Charles I.	1636	No livery; yet have a master, 2 wardens, and 18 assistants.	
70	Needle-makers	No hall	O. Cromwell	1656	5 5 0	
71	Gardeners	No hall	James I.	1616	No livery; yet have a master, 2 wardens, and 18 assistants.	
72	Soap makers	No hall	Charles I.	1630	No livery; yet have a master, 2 wardens, and 18 assistants.	
73	Tin-plate-workers	No hall	Charles II.	1670	10 0 0	
74	Wheelwrights	No hall	Charles II.	1670	15 15 0	
75	Distillers	No hall	Charles I.	1638	13 6 8	
76	Hatband-makers	No hall	Charles I.	1638	Incorporated with the company of needle-makers.	
77	Patten-makers	No hall	Charles II.	1670	6 0 0	
78	Glass-sellers and looking-glass-makers	No hall	Charles II.	1664	5 0 0	
79	Tobacco-pipe-makers	No hall	Charles II	1663	No livery; yet have a master, 2 wardens, and 18 assistants.	
80	Coach and harness-makers	Noble-street	Charles II.	1677	10 0 0	
81	Gunsmiths	No hall	Charles I.	1638	10 0 0	
82	Gold and silver wire-drawers	No hall	James I.	1623	No livery; yet have a master, 2 wardens, and 18 assistants.	
83	Long-bow-string-makers	No hall	No charter		No livery; yet a company by prescription, and	

	Companies	Halls.	Inorporated by	A. D.	Livery fines.	Charitable Gifts paid yearly, and Privileges, &c.
84	Card-makers	No hall	Charles I.	1629		No livery; yet have a maſter, 2 wardens, and 18 aſſiſtants.
85	Fan-makers	No hall	Q. Anne	1709		No livery; yet have a maſter, 2 wardens, and 20 aſſiſtants.

86 Woodmongers were a company incorporated with the carmen by K. James I. 1605, but ſurrendered their charter in 1668; by an act of common council in 1694, they obtained a privilege of keeping 120 carts, excluſive of the number kept by the carmen, *extinct*.

	Companies	Halls.	Inorporated by	A. D.	Livery fines.	Charitable Gifts paid yearly, and Privileges, &c.
87	Starch-makers, *extinct*	No hall	James I.	1622		
88	Fiſhermen, *extinct*	No hall	James II.	1687		
89	Pariſh-clerks	Wood-ſtreet	Henry III.	1233		By a decree of the Star chamber court in 1625, they obtained a privilege to keep a preſs in their hall, for printing the weekly bills of mortality, by a perſon appointed by the archbiſhop of Canterbury. They are, by their charter, to make a report of all the weekly chriſtenings and burials in their ſeveral pariſhes every Tueſday, and they have a maſter, 2 wardens, and 17 aſſiſtants.

90 Porters, are another fellowſhip, without hall, or livery; conſiſting of tackle and ticket-porters. They were conſtituted a fraternity by act of common council in 1646, with a power of annually chuſing among themſelves twelve rulers, being ſix of each denomination. However, the court of lord mayor and aldermen have reſerved to themſelves a power of appointing one of their own body, as the chief judge in all controverſies. One very laudable cuſtom of the maſter tackle-porters is, that ſuch of their brethren as happen to be diſabled from working, receive their ſhare of all profits, as if actually in buſineſs, during life.

91 The watermen, wherrymen, and lightermen of this city and neighbouring places, were by act of K. William III. conſtituted a ſociety, or company, under the direction of the lord mayor and aldermen. They are to furniſh 1000 men for the navy, upon demand by the admiralty. They have a hall at Coal Harbour, near the Thames; and pay to their poor about 800 *l.* a year; chiefly raiſed by ferries over the Thames on Sunday.

N. B. The company of Surgeons, Pariſh-clerks, Porters and Watermen, have not the privilege of making their members freemen of the city of London.

From the foregoing liſt, it appears on the whole, that there are ninety-one companies, forty-eight halls, and that the number of liverymen, according to the moſt exact account that could be procured, in 1779, was 8954, but this number is variable. The ſums of money yearly diſtributed in charity by only twenty-three of the companies, amounts to more than 23,655 *l.*; and if but fortypounds each be annually given by the remaining ſixty-eight companies, the whole will much exceed 26,375*l.* per annum.

Company ſeems more peculiarly appropriated to thoſe grand aſſociations, ſet on foot for the commerce of the remote parts of the world; as the Engliſh and Dutch Eaſt India company, South Sea company, Miſſiſſippi company, &c.; the riſe and eſtabliſhment of which, we ſhall here ſet before the reader.

However injurious companies with joint-ſtock, and incorporated with excluſive privileges, may, at this time, be reckoned to the nation in general; it is yet certain that they were the general parent of all our foreign commerce: private traders being diſcouraged from hazarding their fortunes in foreign commerce, until the method of traffic had been firſt ſettled by joint-ſtock companies. From this principle it is, that we find ſeveral nations that are now endeavouring to improve their trade, and to eſtabliſh or increaſe marine power, by the means of joint-ſtock companies.

But ſince the trade of this kingdom, and the number of traders have increaſed, and the methods of aſſurance of ſhipping and merchandiſe, and the navigation to all parts of the known world have become familiar to us; theſe companies, in the opinions of moſt men, have been looked upon in the light of monopolies: their privileges have therefore been leſſened from time to time, in order to favour a free and general trade; and experience has ſhewn, that the trade of the nation has advanced, in proportion as monopolies have been diſcouraged. When companies do not trade upon a joint-ſtock, but are obliged to admit any perſon properly qualified, upon paying a certain fine, and agreeing to ſubmit to the regulations of the company, each member trading upon his own ſtock, and at his own riſk, they are called *regulated companies*. When they trade upon a joint-ſtock, each member ſharing in the common profit or loſs in proportion to his ſhare in this ſtock, they are called *joint-ſtock companies*. Such companies, whether regulated or joint-ſtock, ſometimes have, and ſometimes have not, excluſive privileges. Regulated companies reſemble, in every reſpect, the corporations of trades, ſo common in the cities and towns of all the different countries of Europe; and are a ſort of enlarged monopolies of the ſame kind. As no inhabitant of a town can exerciſe an incorporated trade, without firſt obtaining his freedom in the corporation; ſo in moſt caſes no ſubject of the ſtate can lawfully carry on any branch of foreign trade, for which a regulated company is eſtabliſhed, without firſt becoming a member of that company. Of companies of this kind we have had, or ſtill have, in Great Britain, the Hamburgh company, the Ruſſia company, the Eaſtland company, the Turkey company, and the African company. Regulated companies, as ſir Joſhua Child has obſerved, though they had frequently ſupported public miniſters, had never maintained any forts or garriſons in the countries to which they traded; whereas joint-ſtock companies frequently had. And in reality, ſays Dr. Smith, (Wealth of Nations, vol. iii. p. 116.) the former ſeem to be much more unfit for this ſort of ſervice than the latter; partly, becauſe the directors of a regulated company have no particular intereſt in the proſperity of the general trade of the country, for the ſake of which ſuch forts and garriſons are maintained; whereas the private intereſt of the directors of a joint-ſtock company, is connected with the proſperity of the general trade of the company, and with the maintenance of the forts and garriſons which are neceſſary for its defence; and partly, becauſe the directors of the latter company have always the management of a large capital, the joint-ſtock of the company, a part of which they may frequently employ, with propriety, in building, repairing, and maintaining ſuch neceſſary forts and garriſons; whilſt

the directors of a regulated company, having the management of no common capital, have no other fund to employ in this way, but the casual revenue arising from the admission fines, and from the corporation duties imposed upon the trade of the company.

Joint-stock companies, established either by royal charter or by act of parliament, differ, in several respects, not only from regulated companies, but from private copartneries. 1st. In a private copartnery, no partner, without the consent of the company, can transfer his share to another person, or introduce a new member into the company. Each member, however, may, upon proper warning, withdraw from the copartnery, and demand payment of his share of the common stock. In a joint-stock company, on the contrary, no member can demand payment of his share from the company; but each member can, without their consent, transfer his share to another person, and thereby introduce a new member. 2dly. In a private copartnery, each partner is bound for the debts contracted by the company to the whole extent of his fortune; whereas, in a joint-stock company, each partner is bound only to the extent of his share. The trade of a joint-stock company is always managed by a court of directors, which is frequently subject, in a variety of respects, to the controul of a general court of proprietors; but these proprietors, being for the most part totally exempted from trouble and from risk, beyond a limited sum, receive contentedly such half-yearly or yearly dividends, as the directors think proper to assign; and many persons are encouraged to become adventurers in joint-stock companies, who would, upon no account, hazard their fortunes in any private copartnery. The directors of such companies being the managers rather of other people's money than of their own, it cannot well be expected, that they should watch over it with the same anxious vigilance with which the partners in a private copartnery frequently watch over their own. Negligence and profusion must always prevail, more or less, in the management of the affairs of such a company. It is upon this account that joint-stock companies for foreign trade have seldom been able to maintain the competition against private adventurers. They have, accordingly, very seldom succeeded without an exclusive privilege, and frequently have not succeeded with one. Without an exclusive privilege, they have commonly mismanaged the trade; with an exclusive privilege, they have both mismanaged and confined it. For other appropriate and just observations on this subject, in its reference to the African company, the Hudson's bay company, the South Sea company, and the East India company, see Smith's Wealth of Nations, vol. iii. chap. 1.

When a company of merchants undertake, at their own risk and expence, to establish a new trade with some remote and barbarous nation, it may not be unreasonable to incorporate them into a joint-stock company, and to grant them, in case of their success, a monopoly of the trade for a certain number of years. It is the ancient and most natural way in which the state can recompense them for hazarding a dangerous and expensive experiment, of which the public is afterwards to reap the benefit. A temporary monopoly of this kind may be vindicated upon the same principles upon which a like monopoly of a new machine is granted to its inventor, and that of a new book to its author. But upon the expiration of this term, the monopoly ought certainly to terminate; the forts and garrisons, if it was found necessary to establish any, to be taken into the hands of government, their value to be paid to the company, and the trade to be laid open to all the subjects of the state. Without a monopoly, however, a joint-stock company, as experience has shewn, cannot carry on any branch of foreign trade. An eminent French author, of great knowledge in matters of political economy, the abbé Morellet, gives a list of 55 joint-stock companies for foreign trade, which have been established in different parts of Europe since the year 1600, and which, according to him, have all failed from mismanagement, notwithstanding they had exclusive privileges. Although he has been misinformed with regard to the history of two or three of them, which were not joint-stock companies, and which have not failed; yet there have been several joint-stock companies, which have failed, and which he has omitted.

The only trades which it seems possible for a joint stock company to carry on successfully without an exclusive privilege, are those, of which all the operations are capable of being reduced to what is called a routine, or to such an uniformity of method as admits of little or no variation. Of this kind is, first, the banking trade; secondly, the trade of insurance from fire, and from sea-risk and capture in time of war; thirdly, the trade of making and maintaining a navigable cut or canal; and fourthly, the similar trade of bringing water for the supply of a great city. To render the establishment of a joint-stock company perfectly reasonable, with the circumstance of being reducible to strict rule and method, two other circumstances ought to concur. First, it ought to appear with the clearest evidence, that the undertaking is of greater and more general utility than the greater part of common trades; and, secondly, that it requires a greater capital than can easily be collected into a private copartnery. In the four trades above-mentioned both these circumstances concur.

The joint-stock companies, says this judicious writer, which are established for the public spirited purpose of promoting some particular manufacture, over and above managing their own affairs ill, to the diminution of the general stock of the society, can, in other respects, scarce ever fail to do more harm than good. Notwithstanding the most upright intentions, the unavoidable partiality of their directors to particular branches of the manufacture, of which the undertakers mislead and impose upon them, is a real discouragement to the rest, and necessarily breaks, more or less, that natural proportion which would otherwise establish itself between judicious industry and profit, and which, to the general industry of the country, is of all encouragements, the greatest and the most effectual.

Company, *African*; sometimes called "Royal African Company," the name of the original institution. The first commercial voyage from England to the coast of Guinea was in 1536, but nothing like a company was formed till the year 1588, when queen Elizabeth granted a patent for ten years to come, to some merchants of Exeter, and other persons for an exclusive trade to the rivers Senegal and Gambia. In 1618, king James I. granted a charter for establishing a joint-stock company; but separate traders continuing to resort to the coast, the company was soon dissolved. Another company was erected by charter in 1631, which met with little success; and in 1651, the parliament granted a charter for five years to the East India company, for trading to the Gold coast in their way to India. The demand for negroes in the West India and American plantations increasing considerably, another exclusive African or Guinea company was incorporated in 1662, at the head of which was the duke of York, joined with many persons of rank and distinction. This company, like those that had preceded it, was unsuccessful, and its charter was soon after revoked by consent of the parties associated in the enterprize; in consequence of which another exclusive company

was incorporated by letters patent in 1672. They raised a capital of 111,000*l.* and improved the trade considerably; but at the revolution, the West India planters joined the separate traders in asserting that they were always best served with slaves when the trade was free to all persons; and exclusive companies, whose privileges had not been sanctioned by parliament, being considered inconsistent with the declaration of rights, the trade became open again; but all private traders were to pay 10 per cent. to the company, towards maintaining the forts and factories on the coast. This contribution was however found insufficient, and in 1730 parliament granted 10,000*l.* for the purpose, which was continued annually till 1744, when, in consequence of the war, 20,000*l.* was granted, and in almost every year since, a sum has been appropriated by parliament to this purpose.

As all the joint-stock companies which had been established for this trade had appeared incompetent to carry it on with advantage, it was in 1750 (23 Geo. II. c. 31.) transferred to a regulated company, the members of which are deemed a body corporate and politic, under the title of *The Company of Merchants trading to Africa*, but are prohibited from trading in their corporate capacity, from having any joint or transferable stock, and from borrowing money under their common seal. Any person intending to trade to Africa, may become free of this company on payment of forty shillings; and out of the monies thus received, a sum not exceeding 800*l*, is allowed for the salaries of clerks and agents at London, Bristol, and Liverpool, the house-rent of their office at London, and all other expences of management, commission, and agency in England. What remains of this sum, after defraying these different expences, they may divide among themselves, as compensation for their trouble, in what manner they think proper. The forts, factories, &c. possessed by the old company on the coast of Africa, are vested in the present company, who continue to receive an annual sum from parliament (generally about 13,000*l.*) for the support of these establishments: the sum granted in the year 1806 was 18,000*l.* For the proper application of this sum, the committee is obliged to account annually to the cursitor baron of the exchequer, which account is afterwards to be laid before parliament.

The company is under the management of a committee of nine persons, three being chosen for London, three for Bristol, and three for Liverpool, annually. The committee are enjoined to lay an annual account of the application of the money granted to them before parliament.

Although by the 4th of Geo. III. c. 20. the fort of Senegal, with all its dependencies, had been vested in this company, yet in the year following (by the 5th of Geo. III. c. 44.) not only Senegal and its dependencies, but the whole coast from the port of Sallee, in South Barbary, to cape Rouge, was exempted from the jurisdiction of that company, and vested in the crown; the trade to it being declared free to all his majesty's subjects.

Before the establishment of the Royal African company, there had been three other joint-stock companies successively erected one after another, for the African trade. They were all equally unsuccessful. They all, however, had exclusive charters, which, though not confirmed by act of parliament, were in those days supposed to convey a real exclusive privilege.

Companies, *English.* The *East India Company* was established by charter dated Dec. 31, 1600, by which the earl of Cumberland and 215 other persons were authorized to carry on an exclusive trade to all parts of the East Indies, for 15 years; under the title of "The Governor and Company of Merchants of London trading to the East Indies." They raised 72,000*l.* in shares of 50*l.* each, and fitted out five ships, which accomplished their first voyage very successfully, in two years and seven months.

Having carried on the trade for about ten years, with different degrees of success, they obtained another charter dated May 31, 1610, by which the company was made perpetual. They had not yet adopted the mode of trading under one joint stock, but carried it on in several copartnerships and lesser stocks. In 1613 the proprietors of the several separate stocks, united them into one general joint-capital; and notwithstanding some opposition to their trade, both at home, and abroad, they preserved and extended it, having at this time established factories at about twenty different places in India. In a vindication of the East India Company before the privy council, at a subsequent period, among other remarks for shewing the great difficulties attending an East India trade, it was asserted, that although they had a stock of 1,500,000 *l.* yet in fifteen years time, *viz* from 1617 to 1632, their whole profit was no more than 12 and one-half per cent.

In 1637, Charles I. established a new company to trade to China and Japan, but it was soon ruined. The old company likewise from its differences with the Dutch East India company, the encroachments of private adventurers, and other causes, fell into decay, and in 1655 it was dissolved by Cromwell, and the trade laid open. The mischiefs which followed obliged him to re-establish the company about three years after; their joint-stock was now 739,782*l.*, of which only one half, or 369,891*l.* was paid in, and was properly their capital. The total exports of the company in three years, ending with 1660, was 227,820*l.* in bullion, and 23,763 *l.* in merchandize. After the restoration, they obtained a new charter from Charles II. dated April 3, 1661. By this charter it appears that the company had not then one sole transferable joint-stock; but that every one, who was free of this company paid a certain sum of money to the company on the fitting out of their fleet, for which he had credit in the company's books, and received his proportionate dividend on the profits of the respective voyage. The whole investments were made by the company in their corporate capacity; but they were not established as an irrevocable corporation, as they might be dissolved on three years notice.

In 1664, the company's stock sold at only 70 per cent., but in consequence of an inquiry into the state of their affairs, the result of which was very favourable, the stock soon got up considerably. New charters were granted in 1669 and 1676, confirming all their privileges. In the latter year, the company having made a considerable profit by their trade, agreed, instead of making a dividend thereof, to add it to their capital stock, so as just to double the same, by which their capital became 739,782 *l.* 10 *s.* In consequence of the extension and success of their trade, which enabled them to make large dividends, their stock in 1680 sold from 280 to 300 per cent; but these great profits, and the doubtful authority on which they held their exclusive privileges, (not having the sanction of parliament) being a great temptation to individual adventurers, interlopers, who had often given them much trouble, became again very numerous, and attempts were made to get the trade laid open, or to have it vested in a regulated company similar to those by which the trade with Turkey and with some other countries was then carried on. The company, however, in 1683 found means to obtain a new charter, by which all their former privileges were confirmed, and they were empowered to seize the ships and merchandize of all interlopers, to raise and maintain military forces, to exercise martial law,

and to eftablifh a court of judicature for determining all mercantile caufes, within their limits. In 1686 they obtained another charter granting them ftill greater powers and privileges.

Soon after the revolution much popular clamour was raifed againft the Eaft India company; and in 1691 the houfe of commons addreffed the king to diffolve the company and incorporate a new one; an opportunity for which foon occurred, as in 1693, the charter of the company became void, from their not paying the duty which had been impofed on their ftock within the time limited by the act; but a new charter was granted them, on condition of fubmitting to fuch regulations as fhould be ordained before the 29th of September 1694 and which were contained in two charters foon afterwards executed.

In 1698 the complaints of the weavers of London againft the importation of India wrought filks, and the company having been prevented by loffes from making any dividends for feveral years, brought it into much difrepute, and the houfe of commons thought it neceffary to take the ftate of their affairs into confideration. The company thought it prudent to offer to advance 700,000 *l.* for the public fervice at 4 per cent. intereft, provided the exclufive trade was legally fettled on them; but a number of merchants, countenanced by the chancellor of the exchequer, propofed to advance 2,000,000*l.* at 8 per cent. intereft, for fimilar privileges. The latter propofal was approved, and an act paffed by which a new company was eftablifhed; many difficulties however appeared, with refpect to their engaging in the trade, till the expiration of the three years notice for determining the old company. During this unfettled ftate of the Eaft India trade, the old company's ftock had in about nine or ten years fluctuated from 300 per cent. to only 37 per cent.

The great contentions which enfued between the old and new companies, foon rendered it obvious that little benefit would be derived from the trade, unlefs a coalition between the two rival corporations was effected. This was accomplifhed in 1702, by an agreement that the old company fhould purchafe an equal proportion of ftock in the new company, and that the feparate traders, who had fubfcribed to the new company, but not to their joint-ftock, fhould be included in the union. The old company was to keep their ftock in the new company, in their corporate capacity for feven years, then to transfer it to their refpective members, and refign their charter to the crown, from which time the new company comprehending the proprietors of both, affumed their prefent title of "The united Company of Merchants of England trading to the Eaft Indies." In 1708 the term of their exclufive trade to India, which was determinable upon three years notice after 1711, and repayment of the fum they had advanced, was prolonged to three years notice after Lady-day 1726; for which they advanced to government 1,200,000 without any additional intereft. In 1712 they obtained an act for continuing the trade and corporation capacity of the company, although the fums they had advanced to government fhould be repaid; which repayment or redemption of their annual fund, was not to be made till the expiration of three years notice after Lady-day 1733.

The act of parliament being liable to a different conftruction from what was probably intended, and the term granted being near its expiration, a very powerful oppofition to its renewal, was raifed in 1730, and fpecious propofals were made to parliament for redeeming the fund of the company, and transferring the trade to a regulated company, with fimilar privileges. After a very full difcuffion of the fubject, a new agreement was entered into with the company, who agreed to pay 200,000 *l.* towards the fervice of the current year, and to have the intereft payable to them by government reduced from 5 to 4 per cent.; in confideration of which all their exclufive privileges were continued till the expiration of three years notice, to be given after Lady-day 1766, when upon re-payment of their entire capital of 3,200,000*l.* their exclufive privileges were to ceafe, but the company to continue a corporation for ever, to enjoy the Eaft India trade in common with all other fubjects. In confequence of this reduction of the intereft received from government, they thought proper to reduce the dividend payable to their proprietors from 8 to 7 per cent. and foon after to 6 per cent.

In 1743 the company propofed to advance 1,000,000 *l.* for the fervice of the year 1744, at 3 per cent. intereft, on having the term of their exclufive trade enlarged for fourteen years, and being permitted to borrow a million on bonds. This propofal being accepted, the debt from the public to the company became 4,200,000*l.*, and the exclufive trade was now extended to three years notice, to be given by parliament after Lady-day 1780, with the former provifion, that, after fuch determination, the company fhould continue to have a common right with other fubjects in the trade to India.

The company not fubfcribing to the reduction of intereft propofed in 1749, the fpeaker of the houfe of commons was ordered to give them notice that the fum due from government would be paid off, unlefs they fubfcribed before May 30, 1750: with this it was deemed prudent to comply, but a condition was made, that in order to enable the company to reduce their bond debt, they fhould be empowered to raife money by the fale of 3 per cent. annuities, to the amount of the debt of government to the company. The annuities thus fold were known by the title of 3 per cent. India annuities, and were for many years payable at the India houfe, but are now confolidated with the 3 per cent. reduced bank annuities.

Hitherto the company had not afpired beyond their original character of merchants, and merely poffeffed factories at the principal ports to which they traded; thefe factories were, for the fafety of their merchandize and the protection of their fervants, converted into forts, which rendered it neceffary to maintain a military eftablifhment. Thus poffeffed of the means of offence as well as defence, they made confiderable exertions to oppofe the progrefs of the French in thofe parts; and as the two companies each endeavoured to procure the affiftance of the neighbouring native princes, the field of intereft and ambition became much enlarged. In 1751, the company fent a confiderable military force into the province of Arcot to fupport the nabob againft his rival, who was powerfully affifted by the French; in which conteft they were engaged with little intermiffion for feveral years. In Bengal, the company had carried on their commercial intercourfe without any connexion with territorial authority, till the death of the fubah Ali-Verdi-Khan, in 1756. This prince had viewed their increafing opulence and power with great jealoufy, and a fhort time before his death gave a remarkable charge to his fucceffor, in which he cautioned him to keep in view the power of the European nations in his country, and to free himfelf from their influence as foon as poffible. "The power of the Englifh is great; reduce them firft; the others will then give you little trouble. Suffer them not to have forts or foldiers; if you do, the country is not yours." In attempting to put

this advice into execution, Sou-Rajah-Dowla was completely defeated by the company's forces, and the new fubah of their appointment, befides paying to the company a very large fum for their loffes and expences, ceded to them a confiderable territory in the vicinity of Calcutta. On the coaft of Coromandel, hoftilities were carried on againft the French fettlements with unequal fuccefs, but ultimately to the advantage of the Englifh, upon which the fubah of the Decan concluded a treaty with the company, and ceded to them the entire circar of Mafulipatam. In 1760, the company's forces completely defeated thofe of France, and in the following year captured Pondicherry, the chief of the French fettlements in India; fince which events the power of France in India has been very infignificant.

Such was the commencement of the company's acquifitions of territory, which they have feized every fubfequent opportunity of extending, *till* the fovereigns of India, whofe protection they formerly courted, have funk into the fituation of their dependents, and hold their precarious dignities at the will and pleafure of a fociety of foreign traders.

The annual fales of the imports of the company for fixteen years preceding 1757, amounted on an average to about 2,055,000*l.*; and for the fame period, the exported goods and ftores amounted annually, at their prime coft, to 238,000*l.*; the bullion exported to 690,000*l.* per annum, and they paid in difcharge of bills of exchange 190,000*l.* per annum.

Early in 1764, on the receipt of fome unpleafant news from Bengal, India ftock fell 14 per cent. The general adminiftration of the company's affairs, both at home and abroad, became foon after the fubject of much difcuffion; and on 29th Auguft 1766, the court of directors received a notice from the fecretaries of ftate, that an inveftigation would take place in the next feffion of parliament. The adminiftration laid claim to the territories which the company had acquired in India, with the revenue arifing from them, as of right belonging to the crown; but as the company were very unwilling to have this new fource of wealth taken out of their hands, a temporary agreement was made for two years, by which the company, in compenfation for this claim, agreed to pay to government 400,000*l.* a year. In 1769, the agreement was renewed for five years, and the territorial acquifitions and revenues in India fecured to the company for that term, with a ftipulation that the company fhould be allowed to increafe their dividend to 12½ per cent., but not to increafe it more than one per cent. in one year.

They now became involved in a war with the famous Hyder Ally, in confequence of which, and of the mifconduct of their fervants in India, the concerns of the company, from the moft flourifhing fituation, were brought into the greateft embarraffments. Select and fecret committees of the houfe of commons were appointed to inveftigate the ftate of their affairs; and in 1773, it appeared, not only that they were unable to make the ftipulated annual payment to government, but that it was neceffary to affift them with a loan of 1,400,000. Till this fum fhould be repaid, the dividend to their proprietors was not to exceed 6 per cent., and afterward not to exceed 7 per cent. till their bond debt was reduced to 1,500,000*l.* From thefe circumftances, the price of the company's ftock fell confiderably from the latter part of 1772 till February 1774, when their affairs began to wear a brighter afpect. In 1776, the loan from government had been repaid, and their fituation being otherwife improved, the dividend on their ftock was raifed to 8 per cent.

Statement of the Company's Revenues, at their different Settlements in India, in the Year ending April 1777.

To expences in Bengal, civil, military, and fortifications -	£1,350,000	By nett revenues in Bengal - -	£2,500,000
To ditto at Fort St. George	560,000	Benares tribute -	290,000
To ditto at Bombay -	360,000	Oude fubfidy - - - - -	370,000
		By revenues of Fort St. George and the Circars	560,000
	2,270,000	Tanjore fubfidy - -	160,000
Nett balance of the year's revenues	1,770,000	By revenues of Bombay, &c.	160,000
	£4,040,000		£4,040,000

On an average of ten years, ending with 1777, the company's exports in goods were about 490,000*l.*; in bullion, 110,000*l.*; and the fum paid in difcharge of bills of exchange, 458,000*l.* per annum. By the aid afforded from the revenues, their inveftments were increafed, fo as to produce about 3,330,000*l.* per annum.

In 1779, an act was paffed for continuing the territories and revenues in India in the poffeffion of the company for one year, which in 1780 was continued for another year. In June 1781, it was agreed to offer to pay into the exchequer 400,000*l.*, in full difcharge of all claims of the public upon the company up to the 1ft of March; and as, in the preceding year, they had received notice that the 4,200,000*l.* due to them from government would be paid off on the 10th of April, 1783, it became neceffary to enter into a new agreement, the conditions of which were, that the company fhould continue to enjoy their exclufive privileges to the 1ft of March, 1794, then to ceafe and determine, upon the former conditions of three years previous notice, and the repayment of all fums due to them. The furplus of their nett profits, after paying their dividends, were appropriated, three fourths for the fervice of government, and one fourth to be retained by the company; and they were reftricted not to increafe the dividend of 8 per cent. more than 1 per cent. in any year. This reftriction was, however, foon found unneceffary; for the nett profits of the company for the year ending 1ft of March, 1782, did not amount to fo much as a dividend of 8 per cent. on their ftock by 22,023*l.*; in confequence of which, it became neceffary for government to allow a farther time for the payment of 396,466*l.* 2*s.* 6*d.*, which was due from the company for cuftoms, befides a part of the fum which they had agreed to pay in 1781; and they were at the fame time empowered, notwithftanding the above deficiency, to continue their dividends at 8 per cent. In the following year, the war in India, and other circumftances, increafed the embarraffment of the company's affairs; and, by a ftatement of their accounts to the 1ft of March, 1783, it appeared that

the nett profits of that year did not amount to a dividend of 8 per cent. by 255,813*l.*, which dividend they were nevertheleſs authorized by parliament to continue; and, to enable them ſo to do, government iſſued exchequer bills to the amount of 300,000*l.*, which the bank undertook to lend money upon to the company.

The long and expenſive war in which the company had been engaged in India, terminated in March 1784, by the ratification of peace with the Myſorean government; but the conſequence of this war, in addition to the war in Europe, was the general derangement of the company's affairs both at home and abroad. In December 1783, February and May 1784, the directors laid before parliament ſuch accounts as they then poſſeſſed, reſpecting the general ſtate of their finances. But the impoſſibility of drawing any ſatisfactory information from ſtatements made up in ſuch a ſituation of their affairs, with the apprehenſions which the meaſures then in agitation, relative to the future government of India, had excited in the public mind, reduced the credit of the company to the loweſt ebb. Their ſtock ſold as low as 118½; their bonds at home, bearing 5 per cent. intereſt, were negociated from 2½ to 4 per cent. diſcount; their bonds and certificates, at Bengal and Madras, bore from 18 to 40 per cent. diſcount; at Bombay 50 per cent.; and orders on the treaſury there ſold at 65, and upwards, per cent. diſcount.

It now became a general conviction, that the company was incompetent to the political government of the extenſive territories which they had acquired. A Board of Controul was therefore eſtabliſhed, compoſed of a certain number of commiſſioners to be appointed by the king, and removeable at his pleaſure. This board was authorized to check, ſuperintend, and controul, the civil and military government and revenues of the company. The diſpatches tranſmitted by the directors to the different preſidencies were to be previouſly ſubjected to the inſpection of the Board. The appointment of governor-general, preſident, or counſellor in the different preſidencies, was made ſubject to the approbation and recall of his majeſty; and ſuch other regulations adopted, as in a great meaſure deprived the company of that political and civil authority which they had ſuffered to be ſo groſsly abuſed.

In 1786 ſome further regulations were made reſpecting the government of India; and, as the company's trade was increaſing, particularly in the article of tea, their import of which had been greatly augmented by the arrangement of the commutation act, they were ſaid to require a greater capital, and were authorized to create 800,000*l.* new ſtock, on which they raiſed 1,240,000*l.* at the rate of 155 per cent. In 1789 they obtained another act, enabling them to add 1,000,000*l.* to their capital, which thus became 5,000,000*l.*

In the beginning of 1793, the term of the company's excluſive privileges being nearly expired, the ſubject of laying open the trade to India was again diſcuſſed, and though it was not thought proper to riſk the loſs and confuſion which muſt unavoidably attend any attempt to take ſuch an immenſe concern out of the hands in which it has ſo long continued, a ſtipulation was made in the agreement for the renewal of the charter, that ſuch regulations ſhould be adopted as to admit of a free exportation by private perſons on their own account, of any goods of the growth, produce, or manufacture of Great Britain or Ireland; and of a free importation of ſuch ſorts of the raw materials of the Eaſt Indies as are uſed in the manufactures of Great Britain or Ireland; that the company ſhould be obliged to provide ſhipping for the carriage of the private trade, at as low a freight as it could be furniſhed by private merchants; and that they ſhould licenſe a proper number of agents to reſide at the company's ſettlements, under their protection, for the management of the private trade. On theſe conditions the company's term in the excluſive trade was enlarged for 20 years, or to the 1ſt of March, 1814, with the former proviſo, that if, after the expiration of that term, their right to the ſole trade ſhall ceaſe, in conſequence of three years previous notice being given by parliament, and the repayment of ſuch ſums as may be then due from the public, they ſhall continue a corporation, with power to carry on a free trade in common with other perſons.

On this occaſion, the total income of the company, ariſing both from their territorial revenues and their commercial concerns, was ſtated as follows:

The nett annual income in rents and profits of trade, taken in the moſt unfavourable light to the company, and ſuppoſed to be conſiderably under the mark, was rated at - - -		£2,329,164
Subject to the following payments, *viz.*		
Intereſt of 3,200,000*l.* on bond, at 4 per cent. - - - -	£128,000	
Ditto of 6,669,082*l* debt in India, at various rates of intereſt, on a medium about 8¾ per cent. - -	561,923	
Dividend of 8 per cent. on their capital of 5,000,000*l.* - - - - -	400,000	
		1,089,923
Leaving a nett annual ſurplus of - - - -		£1,239,241

Of this ſurplus it was propoſed to appropriate 500,000*l.* per ann. to the reduction of the debt in India, to pay 500,000*l.* per annum to government in half yearly payments, and to pay an increaſed dividend of 10 per cent. to their proprietors on 6,000,000*l.* to which ſum their capital was now raiſed.

This annual ſurplus, if it really exiſted at the time to which the above account refers, was of very ſhort duration. In 1795 the company found themſelves unable to continue the propoſed contribution to government; and the intrigues of Tippoo Saib with the French, and with ſome of the native powers, which obliged the company to keep up a large military eſtabliſhment, and ſoon after to engage in another expenſive war, not only reduced the ſurplus of their revenues, but occaſioned a conſiderable increaſe of debt in India, which has ſince been further augmented in conſequence of hoſtilities with Dowlut Rao Scindia and Jeſwunt Rao Holkar.

In order to furniſh ſome idea of the extent of the company's commercial and financial concerns, the following accounts are ſubjoined.

The amount of all goods ſold at the Eaſt India Company's ſales, from the 1ſt of March 1805 to the 1ſt of March 1806.

Company's goods; *viz.*

Teas - - - - - - - - - - -	£3,620,904	
Bengal piece goods - - - - -	621,862	
Coaſt and Surat piece goods - -	614,317	
Raw and organzine ſilk - - - -	274,459	
Nankeens - - - - - - - - -	65,240	
Pepper - - - - - - - - - -	121,844	
Saltpetre - - - - - - - - -	217,769	
Spices - - - - - - - - - -	114,545	
Drugs, ſugar, coffee, &c. - - -	348,350	
		5,999,290

Private Trade goods, *viz.*

Teas	£239,215	
Piece goods	772,517	
Raw silk	44,228	
Nankeens	21,489	
Pepper	10,633	
Saltpetre	144	
Drugs, sugar, indigo, &c.	1,693,926	
		2,782,152
Total		£8,781,443

An Estimate of the revenues and charges in India, for the year 1806-7.

Revenues.

Bengal	£9,148,711
Madrass	5,021,325
Bombay	677,203
Total	£14,847,239

Charges.

Bengal, civil and military expences	£6,944,607
Madrass do.	5,379,218
Bombay do.	1,826,516
Commercial charges not added to invoices	192,769
Interest of debts	2,275,300
Supplies to Prince of Wales' island, &c.	185,600
Total	£16,804,010
Deduct estimated revenues	14,847,239
Deficiency	£ 1,956,771

Account of the actual receipts and payments of the East India Company, in Great Britain, for one year, ending the 1st of March 1807.

Receipts.

	£	s.	d.
Cash in the Treasury 1st March 1806	669,794	6	2
For company's goods sold	5,294,384	13	8
Of the board of ordnance for saltpetre	160,000	0	0
Private trade goods sold	2,114,269	8	10
Charges and profit on private trade	163,462	19	2
Customs on do.	73,380	19	5
Freight on do.	119,784	18	10
Interest on red. 3 per cent. annuities	36,266	15	10
Of government, on account of a sum due to the company	1,000,000	0	0
Alms-houses at Poplar	2,416	18	2
Persons returned from India	17,516	0	0
Bonds issued	517,000	0	0
Duty on tea received	3,120,290	12	3
Total	£13,288,527	12	4

Payments.

	£	s.	d.
Customs	161,736	14	0
Freight and demorage	1,689,040	9	4
Goods and stores exported	2,270,793	7	8
India debt	50,223	19	5
Bills of exchange from India	342,885	1	8
Ditto from China	641,994	16	8
Bullion exported	514,432	16	8
Charges of merchandize, including supra cargoes, commission, interest on loans, &c.	623,652	14	11
Dividends on stock and interest on bonds	770,429	19	1
Bonds paid off and paid in on sales	216,600	0	0
Proprietors of private trade	2,169,021	15	0
Pay to marine and military officers on furlough, and retired from service	141,319	15	0
Duty on tea paid	3,184,417	6	7
Cash in the treasury 1st March 1807	511,978	16	4
	£13,288,527	12	4

The vast concerns of this company are under the management of twenty-four directors, who are formed into different committees; each committee having the superintendence of a particular department of the company's business. At the general courts of proprietors, persons possessing 1000*l.* stock have one vote; 3000*l.* two votes; 6000*l.* three votes; and 10,000*l.* four votes. The number of proprietors entitled to vote, on the 8th of April 1800, was 2163, and the number of votes 2832.

Company, *Hamburgh*, is the oldest trading establishment in the kingdom; though not always known by that name, nor restrained to those narrow bounds under which it was afterwards confined. It was first called, the Company of Merchants trading to Calais, Holland, Zealand, Brabant, and Flanders: then it acquired the general title of Merchant-adventurers of England; as being composed of all the English merchants who traded to the Low Countries, the Baltic, and the German ocean. Lastly, it was called the Company of Merchant-adventurers of England trading to Hamburgh.

This company was not a society of dealers, each furnishing a part of the sum to constitute the capital stock of the company; but a mere association, or body of merchants, who had nothing in common, but the grant and privilege of trading to Hamburgh, and some other cities of Germany; each managing his own commerce, and trading on his own foundation; only observing a certain discipline, and some regulations, which none but the company could establish or change.

This company was first incorporated by Ed. I. in 1296; and established again, by charter, in 1406, under the reign of Henry IV. It was afterwards confirmed and augmented with divers privileges, by many of his successors; among the rest, by Henry V. in 1413; Henry VI. in 1422; Henry VII. in 1493, 1505, and 1506; Henry VIII. in 1509, 1517, and 1536; Edward VI. in 1547; queen Mary, in 1553; Elizabeth, in 1564, and 1586; James I. in 1605; and Charles II. in 1661. But of all these charters, none but those of Henry IV. Henry VII. Elizabeth, James, and Charles, were of any importance, or gave the company any thing new; the rest being only confirmations. Before the charter of Henry IV. all the English merchants, who trafficked out of the realm, were left to their own discretion, and managed their affairs with foreigners as might be most for their respective interests; without any regard to the general commerce of the nation.

Henry observing this disorder, endeavoured to remedy it, by uniting all the merchants in his dominions into one body; wherein, without losing the liberty of trading each for himself, they might be governed by a company; and be subject to regulations, which should secure the general interest of the national commerce, without prejudice to the interest of particulars. With this view, he granted all the merchants, of his states, particularly those of Calais, then in his hands, a power of associating themselves into a body politic, with

directors and governors, both in England and abroad; to hold assemblies both for the direction of business and the deciding of controversies among merchants; make laws, punish delinquents; and impose moderate duties and taxes on merchandizes and merchants to be employed in the service of the corporation.

These few articles of the charter of Henry IV. were afterwards much augmented by Henry VII. who first gave them the title of Merchant-adventurers to Calais, Holland, &c. gave them a power of proclaiming and continuing free fairs at Calais; and ordered, that to be reputed a member of the society, each person should pay twenty marks sterling; and that the several members should attend the general meetings, or courts, appointed by the directors, whether at London, Calais, or elsewhere.

The inexecution of this last article and contempt of some of the rest, occasioning great inconveniences to the company's affairs, another charter was procured, whereby the pain of imprisonment was menaced, for those who should absent themselves from the meetings without lawful cause, or should disobey the laws. A petition being made to queen Elizabeth, in 1564, for an explanation of certain articles in the charter of Henry VII. and a confirmation of the rest granted by other kings; that princess, by a charter of the same year, declares, that to end all disputes, they should be incorporated anew under the title of the "Company of Merchant-adventurers of England;" that all who are members of the former company should, if they desire it, be admitted members of this; that they should have a common seal; that they should admit into their society what other persons, and on what terms, they please; and expel them again on misbehaviour; that the city of Hamburgh, and neighbouring cities, should be reputed within their grant, together with those of the Low Countries, &c. in that of the former company; that no member should marry out of the kingdom, nor purchase lands, &c. in any city beyond sea; and that those who do, shall be *ipso facto* excluded for ever.

Twenty-two years after this first charter, queen Elizabeth granted them a second; confirming the former, and further granting them a privilege of exclusion, with a power of erecting in each city within their grant, a standing council.

The woollen manufacture being the principal object of their application, they met with great opposition; first, from the Hanse, who forced them frequently to change their mart, or staple; and afterwards under king James I. who having erected a corporation in 1616, in favour of some private persons, who offered to set up a manufacture for dyeing and pressing cloths, &c. under pretence thereof the company of merchant-adventurers were prohibited dealing therein. But that project not succeeding, and the charter being revoked two years afterwards, the merchant-adventurers, whose company had been dissolved two years before, were restored in 1617, to their ancient privileges, and a new charter was given them, confirming their exclusive rights; and allowing them to have officers in the several custom-houses, to have an eye that they were not prejudiced in their woollens, under pretence of the like merchandizes, which others were allowed to send to other parts. This charter of king James, is the last of those confirmed by Charles II. in the grand charter of 1661.

The revolutions which had happened in the Low Countries towards the end of the sixteenth century, and which laid the foundation of the republic of Holland, having hindered the company from continuing their commerce with their ancient freedom; it was obliged to turn it almost wholly to the side of Hamburgh, and the cities on the German ocean; from which change some people took occasion to change its name to that of the Hamburgh company, though the ancient title of Merchant-adventurers is still retained in all their writings.

This society was greatly reduced, when its trade was laid open by William III. and the company is now extinct.

COMPANY *of Merchants of the Staple* was incorporated by Edward III. Their factory was at Middleburgh, in Zealand; but the staple being removed, in 1389, to Calais, it was soon after, *viz.* in 1390, removed from thence to England.

COMPANY, *Russia*. This was first projected towards the end of the reign of king Edward VI. executed in the first and second years of Philip and Mary; but had not its perfection, till its charter was confirmed by act of parliament, under queen Elizabeth, in 1566. It had its rise from certain adventurers, who were sent in three vessels on the discovery of new countries; and to find out a north-east passage to China; these, falling into the White sea, and making up to the port of Archangel, were exceedingly well received by the Muscovites; and at their return, solicited letters patent to secure to themselves the commerce of Russia, for which they had formed an association.

The charter was promised them by Edward VI. but he dying, was first dispatched by queen Mary, in 1555. By this charter, the association was declared a body politic, under the name of the "Company of Merchant-adventurers of England, for the discovery of lands, territories, islands, &c. unknown or unfrequented." Their privileges were, to have a governor, four consuls, and twenty-four assistants, for their commerce; for their policy, to make laws, inflict penalties, send out ships to make discoveries, take possession of them in the king's name, set up the banner royal of England, plant them; and lastly, the exclusive privilege of trading to Archangel, and other ports of Muscovy, not yet frequented by the English.

This charter, not being sufficiently guarded, was confirmed by parliament in the eighth year of queen Elizabeth; wherein it was enacted, that in regard the former name was too long, they should now be called "Company of English Merchants for discovering new trades;" under which name, they should be capable of acquiring and holding all kinds of lands, manors, rents, &c. not exceeding a hundred marks per ann. and not held of her majesty; that no part of the continent, island, harbour, &c. not known nor frequented before the first enterprize of the merchants of their company, situate to the north, or north-west, or north-east of London; nor any part of the continents, islands, &c. under the obedience of the emperor of Russia, or in the countries of Armenia, Media, Hyrcania, Persia, or the Caspian sea, should be visited by any subjects of England, to exercise any commerce without the consent of the said company, on pain of confiscation. The said company shall use no ships in her new commerce, but those of the nation; nor transport any cloths, serges, or other woollen stuffs, till they have been dyed and pressed. That in case the company discontinue of itself to unload commodities in the road of the abbey of St. Nicolas, in Russia, or some other port, on the north coasts of Russia, for the space of three years, the other subjects of England shall be allowed to traffic to Narva, while the said company discontinues its commerce into Russia, only using English vessels.

This company subsisted with reputation almost a whole century, till the time of the civil wars. It is said, the czar then reigning, hearing of the murder of king Charles I. ordered all the English in his states to be expelled; which the Dutch taking the advantage of, settled in their room

After the restoration, the remains of the company re-established part of their commerce at Archangel, but never with the same success as before: the Russians being now well accustomed to the Dutch merchants, and merchandize.

This company subsists still, nearly on the foot of that of Hamburgh, and the northern and Turkey companies; i. e. each member thereof trafficks for himself, and on his own foundation; only paying an acknowledgement as fine for admission, which was reduced by 10 and 11 W. III. c. 6, to five pounds; besides some other dues imposed, from time to time, for the occasions of the company, and the commerce in general. It is under the direction of a governor, four consuls, and assistants.

COMPANY, *Eastland*, is established on similar ground with that of Hamburgh; from whence it appears to have been dismembered.

Its charter is dated in the year 1579. By the first article the company is erected into a body politic, under the title of the "Company of Merchants of the East;" to consist of Englishmen, all real merchants, who have exercised the business thereof, and trafficked through the Sound, before the year 1568, into Norway, Sweden, Poland, Livonia, Prussia, Pomerania, &c. as also Revel, Koningsberg, Dantzick, Copenhagen, &c. excepting Narva, Muscovy, and its dependencies. Most of the following articles grant them the usual prerogatives, of such companies; as a seal, governor, courts, laws, &c.

The privileges peculiar to this company are, that none shall be admitted a member who is already a member of any other company; nor any retail dealer at all. That no merchant qualified, be admitted without paying 6*l.* 13*s.* 6*d.* By 29 C. II. c. 7. the fee of admission into this company was reduced to 2*l.* That a member of another company, desiring to renounce the privileges thereof, and to be received into that of the East, shall be admitted *gratis*; provided he procures the same favour for a merchant of the East, willing to fill his place. That the merchant adventurers who never dealt in the East, in the places expressed in the charters, may be received as members of the company on paying forty marks; that, notwithstanding this union of the adventurers of England with the company of the East, each shall retain its rights and privileges. That they shall export no cloths but what are dyed and pressed, except a hundred pieces per annum, which are allowed them *gratis*.

This charter was confirmed by Charles I. in 1629, with this addition; that no person of what quality soever, living in London, should be admitted a member, unless he were free of the city.

This company was complained of as a monopoly, and first curtailed by legal authority in 1672; and since the declaration of rights in 1689, exists only in name; but they still continue to elect their annual officers, who are a governor, deputy, and twenty-four assistants.

COMPANY, *Turkey*, or *Levant*. This once flourishing body had its rise under queen Elizabeth, who, in 1581, incorporated a small number of merchants, with the privilege of an exclusive trade to Turkey for seven years. James I. in 1605, confirmed their charter, with the addition of some new privileges. During the civil wars some innovations were made in the government of the company; many persons having been admitted members, not qualified according to the charter, or who did not conform to the regulations prescribed, in consequence of which Charles II., upon his restoration, endeavoured to place it upon its ancient basis, for which purpose he gave them a new charter, containing a confirmation of the old one with some additional articles. By this charter the company was declared to be a body politic, capable of making laws, &c. under the title of "The Company of Merchants of England trading to the Seas of the Levant." The number of members was not limited, but no person residing within twenty miles of London, excepting noblemen and gentlemen of quality, was to be admitted into the company, unless first made free of the city of London: those under 26 years of age were to pay 25*l.* for their admission, and those above that age 50*l.* These fines were reduced by an act passed in 1753, (26 Geo. II. c. 18.) by which it is directed that every subject of Great Britain desiring admission into the Turkey company, shall be admitted within thirty days after such request, and shall enjoy all the liberties and privileges of the company, on paying for such admission the sum of 20*l.*

All persons free of the company may, separately or jointly, export any goods or merchandize (not prohibited) from any place in Great Britain, to any place within the limits of the company's charter, in British or plantation built ships, navigated according to law, at any time, and to any persons whomsoever, being free of the company, or to the sons or apprentices of freemen, so long as they shall remain under, and submit to, the direction of the British ambassador and consuls for the time being; and may also import, in like manner, any commodities purchased within the company's limits, on payment of the government duties, and such impositions as shall be assessed upon all merchandize so exported or imported, or upon ships laden therewith, for defraying the necessary expences of the company.

The company is under the management of a governor, a deputy governor, and fifteen directors; they have also a deputy governor in every city and port where there are any members of the company. They present the ambassador which the king is to keep at the Porte, and elect two consuls for Smyrna and Constantinople; allowing a fixed salary or pension to the ambassador and consuls, and even to their chief officers, as secretary, chaplain, interpreters, and janizaries, that they may not have any pretence for raising any sum whatever on the merchants or merchandize. For defraying these charges the company have power to levy duties on the merchandize imported or exported by their members; but of late years they have frequently found it necessary to apply to parliament for pecuniary assistance.

The commerce of this company was formerly very considerable, having been estimated nearly equal to that of the East India company in extent, and much more advantageous to Great Britain; but the convenient situation of the French ports in the Mediterranean for the Levant trade, gives that country such a decided advantage, that the commerce of Great Britain with Turkey has long been on the decline. In 1797, in order to avoid the hazard to which British vessels in the Levant trade were exposed in consequence of the war, an act was passed giving permission to the members of the Turkey company to import the goods usually brought from Turkey, Egypt, or other parts of the Turkish dominions in the Levant seas, from any port whatsoever, either in British vessels or vessels belonging to any friendly nation, on paying, if in British vessels, the same duties which would have been payable if the goods had been imported directly from the place of their growth, and, if in foreign vessels, the duties to which they were before liable; but no entry of such goods was to be made at the custom house till the importer produced a certificate of his being a member of the Turkey company, and that he had paid the company's duties, and in all respects conformed to the company's regulations.

Company, *South Sea*, originated in a project for relieving the government from the embarrassment of a large amount of unfunded debts, and considerable deficiencies in the funds appropriated for the payment of others; the proprietors of these debts being incorporated for the ostensible purpose of establishing a trade to the south seas and the N.W. coast of America. The capital of the company was 9,177,967*l.* 15*s.* 4*d.*; but this being subscribed wholly in government securities, they issued bonds in 1712, for raising 200,000*l.* in cash in order to fit out their first mercantile adventure. In the following year, they obtained the Assiento contract, by which they agreed to import into the Spanish West Indies 144,000 negroes, within the term of 30 years, at the rate of 4800 in each year, and were allowed to send a ship of 500 tons yearly to trade with the Spanish settlements, on condition that the king of Spain should have a fourth part of the gain by such ship, and receive five per cent. on the nett gain of the other three parts. See Assiento.

The first voyage of their annual ship was in 1717, and the company were again empowered to borrow money under their common seal, for carrying on their trade, or to enable them to fulfil an engagement with government to advance two millions towards carrying into execution a proposed reduction of interest on the public debts. On the war breaking out in the following year, a stop was put to their trade with the Spanish West Indies, by the seizure of their effects, by which they sustained a very considerable loss.

Soon after this interruption of their commercial concerns, they engaged in a scheme for converting some of the government terminable annuities into redeemable debts. They had, in 1715, for the accommodation of government, agreed to increase their capital to 10,000,000*l.*, which, by the annuities now purchased, and an advance to government, became 11,746,844*l.* 8*s.* 10*d.*; and although the scheme did not completely succeed, it prepared the way for the much more extensive project of taking in all the public debts, and thus reducing all the public funds which then existed into one.

The mere rumour of this mercantile project raised the price of the company's stock to 126 per cent.; and, in the beginning of 1720, while the bill for carrying it into execution was depending in parliament, their stock got up from 137 to 319 per cent. As the transaction consisted merely in taking the public debts at a fixed price, and giving the proprietors, in exchange, a certain quantity of the company's capital stock, at prices agreed upon between the company and the subscribers, it is evident that the great gain which the company expected to make, could arise only from the current price of their stock being considerably above its real value. By a variety of artifices, and a general stock-jobbing infatuation, it was carried up to the enormous price of 1000 per cent.: the rapidity of its fall, however, exceeded that by which it rose, as it was in a few weeks down to 130 per cent.; involving in ruin persons of all descriptions who were engaged in the wild speculations of the time. (See Bubble.) Had the transaction completely succeeded, the capital of the company would have amounted to 43,411,399*l.* 6*s.* 11¼*d.*, but from some of the debts remaining unsubscribed, it became 37,802,483*l.* 14*s.* 0½*d.* of which four millions were purchased in 1722 by the bank, and in the following year the remainder was divided into two equal parts, one of which was to be called the trading capital of the company, and the other to be distinguished by the title of "The joint stock of South Sea annuities," since called old South Sea annuities.

In 1724, the company undertook the Greenland whale fishery, which turned out very unprofitable: after eight voyages, they sold their ships, stores, and utensils, and found that their whole loss upon this business, capital and interest included, amounted to 237,142*l.* 6*s.* 2*d.*

In 1733, three fourths of their trading capital, which had been reduced by sums paid off in 1727, 1729, and 1732, to 14,651,103*l.* 8*s.* 1*d.*, was converted into an annuity stock called "New South Sea Annuities," only one fourth remaining as their trading stock; and, in the following year, they petitioned the king to be allowed to dispose of the trade and tonnage of their annual ship under the Assiento contract, on account of the little profit they made by it, and to accept of such equivalent as they could obtain from the king of Spain, who at length, to put an end to the many disputes which had arisen from this contract, agreed, in 1750, to pay 100,000*l.* to the company, as a compensation for all claims under the Assiento contract, and from that period they have not carried on any trade whatever. The whole business of the company, therefore, now consists in the management of the following public funds.

Their capital stock - -	£3,662,784	8	6
Old South Sea annuities -	11,907,470	2	7
New South Sea annuities - -	8,494,830	2	10
Three per cents., 1751 - -	1,919,600	0	0

The interest received from government on all these funds, is 3 per cent., but the dividend paid to the proprietors of the company's stock, is 3½ per cent.; on the old and new annuities, 3 per cent.

The company is under the management of three governors, and 21 directors; the qualification required for governor, is the possession of 5000*l.* in the company's stock; for sub-governor, 4000*l.*; for deputy-governor, 3000*l.*; and for a director, 2000*l.* Five hundred pounds stock, gives a right to one vote at the general courts; 2000*l.* to two votes; 3000*l.* to three votes; and 5000*l.* to four votes.

Company, *Scotch Darien.* This was established with good prospect at Edinburgh, in 1695, for the commerce of South America. In 1698, they sent an armament and a colony, which they endeavoured to establish in the isthmus of Darien, which parts North and South America; but the English ministry not thinking proper to avow and support the first successes of the company, which had alarmed Spain, ever jealous of this part of her territories, the Scotch colony was dispersed by the Spaniards in 1699, and thus vanished the best project that ever was formed for disputing with that nation the possession of those countries, from which she pretends to exclude all other nations.

Company, *Hudson's Bay*, was incorporated by charter, dated the 2d of May, 1670, under the title of "The Governor and Company of Adventurers of England, trading into Hudson's Bay," with the exclusive privilege of trading to all parts within the entrance of the streight commonly called Hudson's streights. The charter, however, not being confirmed by act of parliament, the company possess no exclusive rights whatever, any British subject being at liberty to sail into Hudson's Bay, to fish or traffick with the Indians as freely as the company; all the advantage the company have over other adventurers thither is merely the benefit of their own forts, such as they are, by which their agents can reside in so inhospitable a country during the winter, preparatory to their trading with the Indians against the arrival of their ships in the summer. According to the evidence given before a committee of the house of commons in 1749, the company then possessed four small factories, erected at the mouths of the principal rivers, in which they employed about 130 per-

fons, and two fmall houfes with only eight men in each; thefe buildings are neceffarily ftrong, as well to guard againft the climate as againft other dangers, and are furnifhed with artillery to command refpect from the Indians; they have therefore been generally called forts, although no military force is kept for defending them: their inutility in refifting any ferious attack, was obvious in 1782, when the French, who at former periods had done the company much injury, deftroyed their fettlements, forts, merchandize, &c. to the eftimated amount of near 500,000 *l.*

The capital of the company, it is faid, does not exceed 110,000 *l.* which is divided among a very fmall number of proprietors. The commerce carried on by them is not of great extent, as it feldom employs above four or five fhips of about 300 tons each. The articles exported by them are coarfe duffle cloth or blanketing, guns, piftols, fword blades, hatchets, powder and fhot, fpirits, tobacco, brafs kettles, buttons, fifh hooks, looking glaffes, &c.; the imports confift of large quantities of beaver fkins, and peltry of all kinds, bed feathers, quills, caftoreum, whalefins, oil, and a few fmaller articles.

The company is under the management of a governor, deputy governor, and a committee of feven members.

COMPANY, *Sierra Leone*, was fet on foot in the year 1791, with the philanthropic view of introducing civilization into Africa. The principal means propofed for effecting this end was the eftablifhment of a fecure factory for carrying on an extenfive commercial intercourfe with the interior; but before the arrangements for this purpofe were completed, the reception into the fettlement of near 1200 blacks, who had taken part with Great Britain in the American war, and had petitioned the government to be removed from Nova Scotia on account of the coldnefs of the climate, involved the company in confiderable difficulties, and gave a new character to the undertaking. Their expences, from various caufes, became much greater than could have been forefeen, amounting in the firft two years and a half to 111,500 *l.* and were ftill further increafed in 1793 by the war, which at the fame time greatly interrupted their trade, and fubjected them to depredations. In October 1794, the colony was attacked by a French fquadron, and all the moveable property of the company was either carried off or deftroyed, every building belonging to them burnt, and feveral fhips captured. The company's lofs on this occafion has been eftimated at 52,000 *l.* This calamity, combined with their previous expences, fo greatly diminifhed the company's funds, as to lay them under a neceffity of contracting their trade, and reducing confiderably the fcale of their eftablifhment, which had been at all times fo limited as fcarcely to afford fufficient means of tranfacting the bufinefs and attending to the various wants of an infant fettlement.

In the year 1798 the colony had made confiderable progrefs, notwithftanding the many obftacles to its advancement. The town confifted of about three hundred houfes, with the neceffary public buildings, and had become a place of confiderable refort. It was eftimated that from one to two hundred natives vifited the fettlement every day, many of them coming from a diftance of eighty or a hundred miles, for the purpofe of exchanging articles of African produce, for Britifh manufactures. The total number of inhabitants of the colony at this time was about 1200.

In 1800 the company obtained a charter, creating their fettlement an independent colony, and authorizing the directors to frame laws for its government, to appoint a governor and council, and to make other arrangements for the adminiftration of juftice; a fmall military force was at the fame time fent for the defence of the colony. The fum of 7000 *l.* being part of the fum granted by parliament for the maintenance of African forts, was paid to the company for the erection of a fort; 10,000 *l.* was about the fame time received from government as a partial indemnification for the expence to which the company had been put in fettling the Nova Scotians; 4000 *l.* was alfo granted for the fupport of the civil government of the colony. About this time the company agreed to receive in their colony the Maroon Indians, and foon after their arrival, employed them to quell an infurrection among the Nova Scotians, who had endeavoured to poffefs themfelves of the government. A more ferious attack on the colony was afterward made by fome of the native chiefs in the neighbourhood, which rendered it neceffary to adopt additional means of defence.

The fums fince granted by parliament for defraying the charges of the civil eftablifhment of the company, and for the erection of fortifications, have been as follow:

For the year	1801	£ 4,000
	1802	10,000
	1803	14,000
	1804	14,000
	1805	14 000
	1806	18,000

The trade of the company appears to have been fuccefsful, fuppofing it to have been burthened only with thofe charges which are ftrictly commercial, and to have been exempt from the extraordinary loffes by fire, and the deftruction of the fettlement which it has had to fuftain. The abolition of the flave trade will remove fome great obftacles to the fuccefs of this laudable undertaking, and probably enable it to improve and extend its commercial intercourfe with the natives very confiderably.

COMPANY, *for the Manufacture of Flour, Meal, and Bread.* During the diftrefs occafioned by the great fcarcity of corn, in the year 1800, a number of perfons formed themfelves into a company, for the purpofe of eftablifhing in London a manufactory of flour, meal, and bread, to be fold out at reafonable prices. They were incorporated by parliament, and empowered to fubfcribe a joint capital, not exceeding 120,000 *l.* in fhares of 25 *l.* each; their profits being limited to 10 per cent., and the furplus, if any, to be at the difpofal of parliament. They were limited to fell only 120,000 facks of flour, or meal in a year, to make only 200 facks into bread in a week, and to fell not more than 1000 quarters of wheat in any one week. The managers of the company were prohibited from dealing in corn, flour, or bread, for their own private account; and were required to lay before parliament an annual ftatement of their receipts and payments, of the quantities of grain purchafed, with the prices paid for the fame, of the quantities of grain and flour in ftore, of the quantities of flour and bread manufactured by the company, and of the debts and credits of the company, with the names of all the members of it, and the number of fhares held by each. By thefe regulations fufficient publicity is given to the concerns of the company to prevent it from ever being perverted from the original principle of the eftablifhment, and made fubfervient to fchemes of monopoly or fpeculation; and though upon the fcarcity ceafing, they difcontinued making bread, they have carried on the manufacture of flour and meal, and probably contributed to prevent thefe effential articles from being unneceffarily enhanced in price.

The total quantity of wheat purchased by the company in the year 1806, was 9182 quarters, for which they paid 31,655*l.* 19*s.*; the quantity of flour manufactured was 10,536 sacks. The number of proprietors of the company was 330.

The king by an order in council may dissolve this company on six months previous notice being given.

COMPANY, *Dock*. See DOCK.

COMPANY, *Dutch East-India*, had its rise in the midst of the struggle which that people had for their liberty; for the Spaniards having forbid all commerce with them, and shut up all their ports, necessity inspired some Zealanders to seek a new north-east passage to China.

This enterprize proving unsuccessful to three several armaments in 1594, 1595, and 1596, a second company was formed under the name of the "Company of remote Parts;" which, in 1595, took the ordinary route of the Portuguese to the Indies, and returned in two years and a half's time, with little gain, but good hopes.

This company, and a new one just established at Amsterdam, being united, equipped other fleets; and these occasioned other companies at Amsterdam, Rotterdam, in Zealand, &c, insomuch that the states soon began to apprehend they might be prejudicial to each other. Under this concern they called all the directors of the several companies together, who all consented to the union, the treaty whereof was confirmed by the states in 1602, a very remarkable epocha, as being that of the most solid and celebrated establishment of commerce that ever was in the world.

At this time they obtained a charter from the states; and prevailed upon that body, by administering to its exigencies in the Spanish war, to grant them the exclusive privilege of trading to the southern parts of Africa, for a short term of years. The company's capital of 6,500,000 florins (about 541,833*l.* sterling) was divided into transferable shares, or *actions*, as they are called on the continent, of 3000 florins (about 250*l.* sterling each), which were all speedily bought up. The superiority of their trading capital, together with their greater skill in commerce and navigation, enabled them to undersell all other nations, even in the foreign markets of Europe. As they also fixed the prices of their merchandize to all consumers, their profits for some years were enormous. The annual dividends for the 6 years ending in 1610 were as high as 36 per cent.; and in a short time, the actions rose from 3000 to 15,000, and at one time stood as high as 24,000 florins, 8 times the amount of their prime cost. The charter, first granted in 1602, and since renewed from time to time, conferred upon them, besides the exclusive right of trading to the East, the sovereignty (under the superintendence of the states-general) of all the territories which they might acquire in that part of the world, by purchase, treaty, or conquest, with the full power of appointing their own servants; of raising whatever force they might deem necessary for the defence of their territories; and of enacting laws for the internal administration of their dominions. In consequence of this charter, the most extensive that was ever granted to any trading corporation, the company proceeded to arrange their establishment, both in Europe and the East Indies. Their affairs were under the management of sixty directors, divided into several chambers; twenty in that of Amsterdam, twelve in that of Zealand, fourteen in that of Delft and Rotterdam, and a like number in those at Sluys and Horn. As each grant expired the company was obliged to procure a new one, which it has already done, four times since the first; *viz.* one in 1623, for forty-one years, like the first; another for twenty-one years, commencing in 1643; and a third in 1665, for forty years; a fourth in advance, commencing in 1698, to end in 1740. Each grant cost the company a considerable sum; that of 1647 cost 1,600,000 guilders, and the two following ones more; that of 1698 was confirmed by a placard of the states general, granted them an exclusive privilege, which was prolong'd in 1761, for thirty years more. The average premium paid for these renewals was about 270,000*l.* sterling, or three millions of florins.

Their factories, residences, &c. in the East Indies, were very numerous; reaching from the Persian gulf to the coast of China: the principal was that of Batavia, the centre of their commerce: here resided the general, with the state and splendor of a sovereign prince; making war and peace with the eastern kings and emperors at pleasure. They had also several other considerable factories on the coast of China, in Japan, Malacca, Surat, Amboyna, Banda, Siam, Moluccas, &c. several on the coast of Coromandel, and at Ispahan, Cape of Good Hope, &c. in all, they numbered forty factories, and twenty-five fortresses. They engrossed the whole trade of the spicery in their own hands.

At so early a period as the year 1616, this company had no less than 45 large vessels engaged in war and trade, with 10,000 soldiers and sailors in their service, and 4,000 pieces of artillery. However, the flourishing state of their affairs was of short duration. The mismanagement and plunder of the company's servants, and the disputes in which their cruelties, avarice, and imprudence involved them with the native powers during the 17th century, and the dissensions which arose among the different chambers of the general direction at home, greatly reduced the trade, wealth, and power of the institution. The expence of the military establishment also increased; so that at the end of the 18th century, it amounted to 80 vessels, carrying from 30 to 60 guns, and 25,000 men, soldiers included, while the whole dominions in Java, and its dependencies, were farmed for 361,260 dollars. The directors acknowledged that, in 1780, their loss in the war had exceeded 10 millions of florins, nearly twice the amount of their original capital. In the 18th century the Ostend East India company excited the jealousy of the Dutch company. In 1721, a law was passed by the states, prohibiting their subjects from sailing under the Ostend colours, upon pain of death: and in 1731, this unfortunate association was dissolved in consequence of representations from the different European states interested in the East Indian trade; among which Holland, that is the Dutch company, took the lead. Various precautions have been used to support the credit of this company, some of which were oppressive to the country; nevertheless, its shares have continued to fall with augmented rapidity. In the period from 1605 to 1779, the dividends have varied from 75 to 10 per cent.; and in many years no dividend at all was issued. From 1605 to 1610 (both inclusive), the dividend was, at an average, 36 per cent. From 1610 to 1648, the average was only 21; and from 1771 to 1780, it was no more than 12½ per cent. The price of the actions, which had at first risen to 500, and even 800 per cent. of the prime cost, fell, in the period from 1770 to 1780, to about 340 per cent., and during that time continued regularly to fall. The last dividend this once flourishing company made to their proprietors was in the year 1796; but it was not paid till 1799, as their commerce, which had been rapidly declining for the last 30 years, was entirely suspended.

Company, *Dutch West India*, was established in 1621, with an exclusive privilege to trade twenty-four years along the coasts of Africa, between the tropic of Cancer and Cape of Good Hope; and in America, from the south point of Newfoundland, through the straits of Magellan, that of Le Maire, or others, to the straits of Anian, both in the north and south Sea.

Besides these commercial privileges, the states conferred upon the corporation the right of governing and defending any new colonies which it might acquire; and made it a present of several large vessels, well manned. They retained to themselves, however, the nomination of the company's governor-general abroad. The original capital of this association amounted to 72,000 florins, in transferable shares, or actions, of 6000 florins each.

The 74 directors were divided into five chambers (as in the East India company), out of which, eighteen, with a deputy appointed by the states, were chosen for the general direction of affairs. In 1647, the company renewed its grant for twenty-five years; but it was scarce able to hold out the term, on account of its great losses and expences in taking the bay of Todos los Santos, Fernambuc, and the greatest part of Brasil, from the Portuguese. The weakness of this company, which had several times in vain attempted to be joined to that of the East Indies, occasioned its dissolution at the expiration of its grant

In 1674, a new company, composed of the ancient proprietors and their creditors, was settled in the same rights and establishment with the former. It was to undertake the burden of the old company's debt, amounting to six millions, but reduced to 30 per cent.; and was to accredit in its books the proprietors of the old company's stock, at the rate of 15 per cent. The creditors, on their part, were to advance an addition of 8 per cent. on their loans; and the stockholders were to advance 4 per cent. on their shares. The new capital, thus scraped together, amounted only to 630,000 florins. The exclusive commerce of the company was limited to a certain part of the African coast, besides the conquests they should make; and its principal establishments were at Cape Verd, on the Gold Coast, at Tobago, Curassoa, &c. in America. The rest of the trade monopolized by the former company was now thrown open to all the subjects of the republic. In 1730, when the charter was renewed, the African slave-trade was made free, on condition of a certain lastage being paid to the company; and in 1734, the whole African trade was laid open upon the same terms. As the united privileges of the company were not sufficient to counterbalance the various disadvantages under which all fresh institutions labour, they obtained, in 1682, the exclusive management of the colony of Surinam, for the trifling sum of 260,000 florins paid to the states-general. This grant was accompanied by certain conditions, framed with the manifest view of preventing the abuses common to trading corporations. Under these restrictions, the company was not able to defray the expence of the original purchase-money paid for the charter; and, therefore, in the next year, one-third share was sold to the city of Amsterdam, and another to the rich family of Sommelsdyk, reserving the remaining third to themselves. These three co-proprietors have since continued to form a society or partnership, under the name of the "Surinam Company," regulated by the charter originally granted to the West India company. Except in the government of Surinam, this association has had no connection with the West India company, which, of course, continued to furnish negroes to the settlement, in its capacity of African company, until the year 1730.

The progress of the dividends and prices of West India stock will enable us to judge concerning the prosperity, not only of the Surinam society, but also of the concerns of the West India company. The average dividend in ten years, ending 1690, was 2¾ per cent.; and from 1773 to 1779 inclusive, nothing at all was divided. The actions have never been at par; their price has varied from 92½ to 18 per cent. since the year 1723. The average price during ten years, ending 1732, was about 81¼ per cent. During ten years, ending 1779, it had fallen to 32⅘ per cent. The settlements of Essequibo and Demerary have been always under the charter of the West India company, as well as Surinam, and governed in the same manner. Berbice, though within the company's charter, owed its origin to the speculations of the family of Van Peere; and all the cultivated part of the colony belonged to them. In 1678 they obtained a perpetual grant of it from the company, which was confirmed in 1703; and when the French attacked it in 1712, the colony bought them off with a considerable composition. The money was paid by their great mercantile houses, and one fourth of it by the Van Peeres, who thus transferred three-fourth shares of the colony to the other merchants as co-proprietors; and the four houses together formed a copartnery or company at Berbice, administered exactly in the same manner with the Surinam society. The proprietary governments of North America differed from the company administrations of Guiana in many important particulars. They were the consequence of large and thoughtless grants, made by the court to favourites, of waste and uninhabited lands. As the British colonies were subservient to the legislature of the mother-country, the Dutch colonies owed the same allegiance, not to the states-general, but to the proprietors. The ill success of the West India company furnishes an useful example of the manifold evils of company government. This company must of late have been annihilated by the capture of all their settlements.

Company, *Dutch North*, has no exclusive privilege; the advantage of its patent being of another kind, and very considerable.

There are also, in Holland, companies for the Baltic sea, the fishery of Nova Zembla, Davis's Streights, and Greenland: yet none of their fisheries are interdicted to private traders; all the difference between these and the companies consisting in this, that the former may not go ashore to cut their fish in pieces, and melt their lard: but must bring their luggage to Holland.

Company, *Dutch Levant*. In strictness, there is no Levant company in Holland: but the commerce of the private traders is so considerable, that the state has taken the regulation thereof on itself.

To this end, they have established a chamber of direction at Amsterdam, composed of six deputies, and a register; who, under the burgomasters, take care of every thing relating to the commerce of the Mediterranean; especially that of Smyrna and Constantinople.

This company names the consuls, appoints the number and strength of convoys, terminates differences among the traders, and has also a right, on occasion, to add new regulations to the old ones; though those be of no force, till confirmed by the states general.

Company, *French East India*, was established in 1664, with an exclusive privilege to trade for fifty years in all the seas of the East Indies and South Sea; no adventurer to be admitted without a thousand livres in stock; and foreigners, who have twenty thousand livres in stock, to be reputed regnicoles.

The patent grants them the island of Madagascar; and

the king to be at one fifth of the expence of the three first armaments, without interest; the principal to be refunded in ten years: or, if the company finds it loses on the whole, the loss to fall on the king's side.

The capital fund of the company, which was mostly furnished by the king, was seven or eight millions of livres, but was to have been fifteen millions.

In effect, though no means were wanting to support the company, yet it still drooped, and still struggled; till, having subsisted ten years without any change in its form, and being no longer able to discharge its engagements, there were new regulations concerted, but to little purpose. At length, things not being disposed for a new East India company, nor much good to be expected from the old one, in 1708, the ministry allowed the directors to treat with the rich traders of St. Malo, and resign to them their privilege under certain conditions. In the hands of these last, the company began to flourish.

Its chief factory was at Pondicherry, on the coast of Coromandel; this was the residence of the director-general; the other factories were inconsiderable. The merchandizes which the company brought into France were, silks, cottons, spices, coffee, rice, salt-petre; several kinds of gums and drugs, wood, wax, printed calicoes, muslins, &c. The trade was laid open in 1769, which soon reduced the company to a set of mere holders of the government funds. A new company was established in 1785 with the privilege of an extensive trade to all parts of the East Indies, except the Isle of France and its dependencies. This exception must have prevented the company from succeeding; but the experiment had scarcely been made when the trade was again laid open by the national assembly in 1790. As for the other French companies, such has been the state of the country, they are all, we presume, extinct; and it is needless to give any account of them. Such were the *French West India company*, established in 1664, and possessing by their charter the property and seigniority of Canada, Acadia, the Antilles island, the isle of Cayenne, and the Terra Firma of America, from the river of the Amazons to that of Oroonoko; with an exclusive privilege for the commerce of these places, as also of Senegal, and the coasts of Guinea, for 40 years, on condition of paying half the duties; but in 1674 the grant was revoked, partly on account of the poverty of the company, and partly because it had answered the purpose of its establishment by recovering the commerce of the West Indies from the Dutch:—the *French Mississippi company*, first established in 1684, in favour of the chevalier de la Salle, who failed in search of the Mississippi, but miscarried with his colony, and came to an untimely death. He was succeeded by M. Hiberville. who found the Mississippi and settled a colony there; but this adventurer being poisoned, M. Crozat obtained in 1712 the sole privilege of trading to the French territories called Louisiana, granted to him for 15 years:—*Company of the West*, formed in 1717, when M. Crozat surrendered his grant before mentioned; and obtaining besides every thing granted to the former company the commerce of beaver, enjoyed by the Canada company from the year 1706, but expiring in 1717:—*India company*, formed by a junction of the former company with that of Canada and with that of Senegal in 1718, and also by an union with the East India company, and with those of China and St. Domingo, with the two first in 1719, and with the third in 1720;—the *Bastion company*, arising from the association of two merchants of Marseilles in the 15th century for fishing of coral in the gulf of Stora-Courcoury on the coast of Barbary, on the frontiers of Algiers and Tunis; so called from a small fort called the "Bastion of France;" built in 1561, but it sunk in 1633;—and several other companies, which either fell of themselves, or upon the expiration of their grants, and which it is therefore needless to mention.

COMPANY, *Danish North*, was established at Copenhagen in 1647. Its establishments are very considerable in Norway; besides which, it sends vessels to Waranger, whence they convey their merchandizes by land into the Danish Lapland; and by sledges drawn by rein-deer into the Muscovite Lapland. It also sends others for Borandai and Siberia; where its agent takes them up, and conveys them, in like manner, on sledges, to Panigorod, the capital of this part of the Muscovite empire.

The commodities it sends thither are rix-dollars, tobacco, and linens; it returns nothing but furs and skins.

COMPANY, *Danish Iceland*, established in the same year with the North Company, its chief factory is at Kirkebar, a large town in that island.

COMPANY, *Danish East India*, established in the year 1616, and invested not only with the exclusive privilege of trading to the East, but with the powers of civil and military administration; their chief factory was at Tranquebar. In 1634 this corporation was dissolved, and another, with similar privileges, substituted in its place. This also rapidly declined; and in 1686, a third institution was tried for the same purposes; but this too failed in about 23 years; and the project was tried for the fourth time in 1732. The new company was provided with ample privileges and powers; and the possession of these preserved its existence, and increased the profits of the stock-holder, at the expence of the country, and of the Indian settlements. In 1772 the charter expired, and was renewed under restrictions which proved ruinous to the prosperity of the company. In 1777, the king purchased the rights of the company, and the private trade began to flourish. When the charter was renewed in 1792 for 20 years, the private trade was rendered still more free; all Danish subjects, and all foreigners were permitted to trade with the Indian settlements, upon receiving passports, either from Copenhagen or the Asiatic seats of government, and upon condition of returning with the cargoes to Copenhagen.

COMPANY, *Levant, of the Genoese*, established in 1664, and confirmed by the Porte; notwithstanding the opposition of the French. From 1670 this company has languished and sunk.

For a more particular account of the rise and progress of most of the above mentioned and other companies, see "Anderson's Hist. of Commerce."

COMPANY, *New River*. This corporation consists of a governor, deputy governor, treasurer, and twenty-six directors, who hold a weekly board for appointing officers, granting leases, and redressing grievances. The projector of this canal for bringing water to London, with the assistance of king James I. and the corporation of London, is supposed to have expended 50,000*l.* upon it: the profits, which are divided into seventy-two shares, for the first thirty years admitted of little more than five pounds to each share; but their value is much increased, and its original shares of 100*l.* are now estimated at upwards of twelve thousand pounds each.

Condensation

CONDENSATION (from *condensate*, and condensate from the Latin *condensatus*), denotes the contraction of a given quantity of matter into a smaller space, and in this sense only the word condensation ought to be used; however, in common language, the inspissation, the thickening, or hardening of certain compound substances, in consequence of the escape of some of their component ingredients, is frequently expressed by the same term; thus the juices of fruit, of plants, of meats, &c. are often said to be condensated over the fire. Compression and condensation (though sometimes used the one for the other) differ in this; *viz.* that the former denotes a diminution of bulk, occasioned by the application of external force; whereas the latter expresses the same effect, when produced without that external application, as is the case with most bodies in cooling. But the word condensation has been more commonly used for denoting the conversion of vapour into water, or of vapours in general into liquids.

The particulars which might be noticed with respect to condensation are, the quantity and rate of contraction in different bodies, the causes which produce it, and the limits of that contraction. These particulars, however, will, with more propriety, be stated under the articles EXPANSION, THERMOMETER, and PYROMETER, which see.

Notwithstanding the above-mentioned definition, it is to be remarked, that in every case of condensation, or of the contraction of a body into a narrower space, the effect is produced by the escape of something; and in bodies, which seem to be the simplest in nature, the contraction which they undergo in cooling, is occasioned by the escape of the caloric, which the present state of philosophical knowledge reckons amongst the elementary substances. But the reverse of this proposition is not always true; *viz.* bodies are not always contracted in their dimensions when the caloric escapes from them; and such has been found to be the case with water, with iron, and with some other substances, in certain temperatures. This will be rendered more evident in the sequel.

Most bodies are susceptible of three successive states of existence; namely, the solid, the liquid, and the elastic or vaporous; and all these are effected by the introduction of different doses of caloric. During every one of those states, a different degree of condensation is produced by the intermediate gradations of temperature; *viz.* such as are not quite sufficient to induce a different state of existence in the body concerned. Thus, a quantity of the vapour of water, which, at the temperature of 242° (Fahrenheit's thermometer), and under the mean gravity of the atmosphere, occupies the space of 3600 cubic inches; if it be gradually cooled until the temperature becomes equal to about 212°, its bulk will be contracted so as to occupy the half of the space it did before, *viz.* about 1800 cubic inches. If the temperature be lowered below 212°, the vapour will be condensed into liquid water, which will occupy the space of not more than a single cubic inch. If the cooling be continued, the water will be contracted in its bulk, but not very regularly (that is, the decrements of bulk will not be exactly proportional to the decrements of heat); until the temperature descends to about 42°. Below that degree, the water, instead of contracting its bulk, is expanded by further cooling; *viz.* by a further abstraction of caloric. This is a very remarkable property of water, upon which some interesting phenomena of nature are depending. The water, though expanding below the temperature of 42°, still continues fluid as far as about the temperature of 32°; but below this last mentioned point, by farther cooling it becomes a solid; namely, ice; and in this state water occupies a greater space than it did in a liquid state. (See CONGELATION.) Similar irregularities have been observed in the condensations of several other bodies, both solid and fluid; and it is to be wished that experiments capable of determining the laws of condensation were instituted with all those bodies which are at all susceptible of the trial.

The causes of condensation are by no means thoroughly understood. It may seem, at first sight, sufficient to say, that since caloric is an elementary substance, which is combined in various proportions with every other known body, the separation of part of that element from the other bodies, naturally enables the particles of the latter to come closer to one another in virtue of their mutual attraction. But that this cannot be the sole cause of the condensation in its whole extent, is easily pointed out by the following queries. 1st. How are the particles of bodies disposed, that they may be capable of approaching, or of receding from each other? 2dly, Why the degrees, or quantities, of condensation are not always proportional to the degrees of caloric that are abstracted from bodies? And, 3dly, Why clouds, fogs, mists, &c. (which consist of the vapour of water suspended in the atmosphere) are not always condensed into liquid water below the temperature of 212°; which is actually the case in the atmosphere?

It has for a long time been an opinion prevalent amongst philosophers, that the particles of bodies do not actually touch one another; for otherwise it seemed impossible to comprehend how a body could be expanded and condensed. But the least consideration will easily suggest a variety of dispositions of the particles, which, whilst they actually touch one another, will readily admit of the dilatation and condensation of the aggregate. Conceive, for instance (as professor Prevost of Geneva justly observes), the particles to be elongated, and united at their extremities like the legs of a pair of compasses, and they may turn, with regard to this point of union, as a centre, and produce condensations and dilatations of the whole apparent mass of the body. A sponge likewise will dilate in water without interrupting the continuity of its parts. One may also conceive the particles of bodies arranged in the form of rings; that is, many of them to be in absolute contact, one with the next, and this with the following, &c., so as to form circular or oval rings. With this disposition of particles, the dilatation and condensation of the aggregate is nothing more than an alteration of the form of those rings; *viz.* they become more like circles when the body is expanded, and more oblong when the body is condensed; it having been demonstrated by mathematicians, that the circle comprehends an ampler space than any other figure of the same periphery. Though the general disposition of the particles of a body is not known, yet a va-

riety of phenomena clearly indicate that they are not confusedly placed; but that some arrangement, probably a peculiar one, for the particles of each different body, actually takes place; and to this peculiar arrangement some of the effects of dilatation and condensation, at least the irregularities of those alterations, must undoubtedly be attributed. Thus the particles of water crystallize in freezing; that is, they dispose themselves with a peculiar regularity, somewhat resembling the filaments of a feather. These filaments of water form angles of about 60 degrees with a larger filament, which is, as it were, the stem of the feather; and to this crystallization the enlargement of the bulk of water in freezing is with propriety attributed. Such is the force with which the particles of water endeavour to arrange themselves in that particular order, and of course to enlarge the bulk of the aggregate, that several astonishing effects are produced by their united efforts. Pieces of timber, stones, and other bodies, are burst by the freezing of inclosed water. Even iron mortar-shells, such as are used in war, filled with water, and accurately stopped, have been burst by the freezing, and the consequent enlargement of the inclosed water.

Since the enlargement of the bulk of water commences at about the temperature of 42°, which is 10 degrees above the point of melting ice, commonly called the *freezing point*, which is 32°, it is evident that the particles of water begin to arrange themselves in a particular order long before the freezing takes place. And, by following the analogy, it may be supposed, that in every state of existence the particles of bodies have, more or less, a tendency to arrange themselves in a certain order; to which tendency the irregularities in the condensations of bodies are probably to be attributed.

The above-mentioned particulars, respecting the condensation of water, must in great measure be understood to belong to a great variety of bodies; for all those which have been subjected to decisive experiments have been found to contract or to enlarge their bulk with irregularity, in some part at least, if not throughout, the whole scale of heat.

The condensation of vapour in the atmosphere, which is not always accompanied with a proportionate degree of temperature, forms another difficulty, which the present state of philosophical knowledge is not entirely capable of explaining. We shall, however, briefly state certain facts and certain considerations, which ought to be kept in view by those who are willing to investigate this intricate and interesting subject. The conversion of water into vapour is attended with an increase of its capacity for containing heat, or caloric, and likewise with an increase of its capacity for containing electric fluid; so that if a quantity of water, held in an open and insulated vessel, be suffered to evaporate, the vapour will deprive the vessel of part of its heat, and of part of its electric fluid: consequently, the vessel will be cooled and electrified negatively. Now that which philosophers wish to ascertain is, whether the influx of the caloric and of the electric fluid produces the evaporation, or the conversion of the water into vapour draws the caloric and the electric fluid from the contiguous bodies. In the first case, we see no reason why the caloric and the electric fluid should spontaneously quit the contiguous bodies, and run to the water in order to force it to evaporate, because both the water and the contiguous bodies are in an equilibrium; that is, in the same state with respect to temperature as well as of electricity. In the second case, if the influx of heat and of electricity does not force the water to evaporate, what other cause can produce that effect?

The same reasoning which has been applied to the conversion of water into vapour, may, *mutatis mutandis*, be adapted to the contrary effect; *viz.* to the condensation of vapour into water, it being equally difficult to comprehend how the vapour can remain in the elastic state, that is, without being converted into water, at a temperature much lower than 212°, which in the atmosphere is generally the case. There is one consideration, however, which may throw some light upon this remarkable phenomenon; *viz.* that in order to deposit the caloric and the electric fluid, which must necessarily take place in the condensation of vapour, there must be a body or bodies ready to receive both. But in the atmosphere, the only body which can receive them is the air, and it is well known, that air is a bad conductor of heat as well as of electricity. The last remark which we have to subjoin is, that it has been observed with several substances, and especially with water, that though placed in a colder temperature, they do not part with their caloric so easily as it might be expected, and this is particularly the case when they are to undergo a change in their state of existence; thus water will sometimes continue fluid when its temperature is 4 or 5 or even more degrees below 32°; though when once formed into ice, this will not melt at a temperature lower than 32°, and yet it will evaporate if exposed to the air whilst its temperature is many degrees below 32°.

Condenser

CONDENSER, from *condense*, is an inftrument capable of collecting, or of drawing into a fmaller fpace any fcattered matter, or quality, or effect. In philofophy and in mechanics, three different inftruments have obtained the name of condenfers; *viz.* the *condenfer of air*, the *condenfer of electricity*, and the *condenfer of forces.*

The *condenfer of air*, in pneumatics, is a fyringe, by means of which a confiderable quantity of air may be forced into a veffel fitted for the purpofe. Fig. 1 and 2, *Plate* XIV. *Pneumatics*, reprefent two conftructions of this fort of condenfer, which differ but little from each other. They are generally made of brafs or of iron. A B, *fig* 1, reprefents a cylindrical tube, at moft, two inches in diameter, and from 8 to 12 inches in length, or even longer. Its flat bottom B is perforated with a hole, on the outfide of which, a valve, (confifting of a piece of oil filk, or rather of leather, ftretched over a fmall flat piece of brafs), is adapted, fo that if any air be forced from the infide of the cylinder A B, that fluid will eafily lift up the valve, and make its exit through the hole at B. But fhould any fuction take place within the cylinder A B, the air cannot poffibly enter through the hole at B, becaufe the valve on the outfide prevents it by ftopping that hole. The pifton *c d* fits the cavity of the cylinder A B pretty tightly, by means of leathers foaked in oil; and it may be moved up or down by the handle E which is faftened to its rod. This pifton is perforated with a hole *c d*, the lower part of which is furnifhed with a valve *d*, which, when the pifton is drawn upwards, will permit the air to enter the lower cavity of the cylinder; but if the pifton be pufhed downwards, the air which is contained in the lower cavity of the cylinder, cannot pafs through the hole *c d*, on account of the valve at *d;* therefore it will come out through the hole at B. At the extremity of the cylinder, a brafs or iron cap F G is fcrewed over the valve, allowing however a little room for its free motion. The end G of this cap is perforated quite through, and its outfide is formed into a fcrew.

Fig. 2 reprefents a condenfing inftrument fimpler than the preceding, and fuch indeed is at prefent moftly ufed. Neither the cylinder nor the pifton of this inftrument is furnifhed with any valve. There is a hole through the fcrew at the bottom B of the cylinder, and a hole at C through its fide, and at about two or three inches below its upper end; the pifton has no perforation.

When the condenser, *fig.* 1, is screwed into the aperture of a glass or metal vessel, and the piston is moved alternately up and down, it will be readily understood, that the air will be forced into the vessel to which the condenser is adapted; for when the piston is pulled upwards, that is, towards A, the air cannot enter the cylinder through the hole at B, but it can easily pass through the hole *c d*; and when the piston is pushed in, the air which is contained in the cavity of the cylinder, cannot go out of it through the hole *c d*, but it can pass through the hole at B; hence it is forced to enter the vessel to which the condenser is applied. Thus by repeating the movements of the piston, more and more air is condensed into the vessel, until the latter is burst by the elasticity of the condensed air, or the same force pushes so hard against the valve at B, that the strength of the operator is no longer able to overcome it. The condenser, *fig.* 2, is used exactly in the same manner; this, however, must be adapted to such vessels as are furnished with a valve within their aperture, which permits the entrance, but not the exit of the air. When the piston of this condenser is drawn towards C, a vacuum is formed in the lower part of the cylinder, until the lower part of the piston is raised above the hole C; then the air rushes through that hole, and instantly fills the cavity, &c.

These instruments are generally used for condensing the air into the air-holders of wind-guns, of certain water fountains, and other machines. By this means, the air has sometimes been condensed to such a degree, as to become six, eight, and even more times, denser than common atmospherical air. The vessel, in that case, is said to contain respectively six, or eight, or a greater number of atmospheres.

In a variety of philosophical experiments, substances are frequently placed in a glass vessel in which air is condensed, in order to observe its effects upon the enclosed substances. For this purpose, one of the above-mentioned condensers is affixed to a frame and apparatus, as is represented in *fig.* 3.; and this apparatus, all together, is called a *condensing engine*.

C D is a brass condenser, which is worked by applying the hand to the handle Z of the piston, and by moving the latter alternately up and down, the air is forced through the brass pipe D N F into the glass receiver A B. This receiver, which must be very thick and well annealed, is set with its smooth and flat edge upon the brass plate of the machine, which is similar to the plate of an air-pump. A thick piece of brass L M, is applied in a similar manner to the upper aperture of the glass receiver, and a slip-wire passes through a collar of leathers in this brass piece. In order to prevent the lifting up of the brass piece L M from over the glass vessel, or the latter from the plate on the frame of the machine by the force of the condensed air, two pillars of wood with a cross piece G H, likewise of wood, are annexed, for the purpose of keeping down the glass vessel, and the piece of brass L M. The cross piece G H is pressed upon L M by means of the screw-nuts on the pillars I, K. There is a gage E F, annexed to this machine, which indicates the condensation of the air within the glass vessel, and tube of communication. It consists of a strong and narrow glass tube, hermetically closed at E, and connected with the brass tube of communication at F. A small quantity of mercury fills up a short part of the cavity about the middle of the tube, and the space between the mercury and the closed end E of the tube, contains air of the usual atmospherical density. It is by the contraction of this small quantity of air, that the degree of condensation in the glass receiver is indicated; for in proportion as the air is condensed into the receiver, or tube of communication, &c., so the air between the mercury and the closed end of the gage becomes contracted more and more; and the quantity of that contraction is indicated by a scale annexed to the glass tube; for instance, if that air is, by working the machine, compressed into the half of the space it occupied at first, it shews that the air within the receiver is as dense again as it was before the working of the machine. If the air in the gage is compressed into a quarter of its original space, the air within the receiver is shewn to be four times as dense as it was before the working of the machine, and so forth; the condensations in the glass receiver being inversely as the spaces occupied by the air in the extremity E of the gage. These degrees of condensation are commonly expressed by saying, that *the receiver contains two, or three, or four, or more atmospheres*, when the air within it, is twice, or three times, or four times, or more times, denser than the usual air of the atmosphere.

There are certain air-pumps, as those of Smeaton, of Haas and others, the construction of which renders them capable of being used for condensing, as well as for exhausting the air. See Air-pump. In certain forcing water pumps, in fire engines, and some other hydraulic machines, there is a vessel, in which the air is condensed by the action of the machine itself; the object of which is to produce a constant stream of water out of the engine, whilst the piston of it is moved up and down in the usual way. This vessel is called the *air vessel*, and often the *condensing-vessel*, or simply the *condenser*. See Pump, and Fire-*engine*.

The head of an alembic, wherein the vapours are condensed into a liquid, has sometimes been called the *condenser* of the alembic.

Condenser *of Electricity*. This is an instrument capable of collecting, or of condensing into a small space, such quantities of weak and diffused electricity, as would otherwise remain unperceived, or be insufficient to affect even the most sensible electrometer. It was originally invented by a very distinguished philosopher, Mr. Volta of Como, and is by himself described in the 72d vol. of the Philosophical Transactions. But, since its original invention, this instrument has undergone several improvements and alterations, which we shall now describe, together with their peculiar advantages and defects.

The action of electric atmospheres is the principle which suggested the construction of this most useful electrical instrument. Though the nature of these atmospheres will be treated of in the article Electricity; it will, nevertheless, be necessary to give, in this place, some idea of their action, by means of an easy experiment, in order to render the principle upon which the electrical condenser acts, manifest to the reader. Affix an electrometer of pith-balls to an insulated metallic plate; that is, a plate of tin or brass, or other metal, having a glass handle. Communicate some electricity to it, and observe the divergency of the electrometer. In this state, bring the electrified plate near a conductor which is not insulated, such as the wall of a room or another metallic plate, and you will find that the electrometer collapses in proportion as the electrified plate comes near to the uninsulated conductor. Remove the electrified plate, and the electrometer will diverge again, nearly as much as it did at first; which shews, that by the vicinity of the uninsulated conducting body, which could easily acquire the contrary electricity, the intensity of the electricity in the electrified plate was diminished; or, which is the same thing, that the capacity of that plate for containing electricity was increased. Hence, when an insulated metallic plate is situated near another metallic plate not insulated,

the former will thereby be enabled to absorb a much greater quantity of electricity than it otherwise would, from any source whatever; and if the electrified plate be removed from the other, then that absorbed electricity will be manifested by the divergency of the electrometer, or even by affording a spark. It naturally follows, that according as the conductor which is opposed to the insulated plate, is nearer to, or farther off, so the capacity of the plate will be increased more or less. Such an insulated plate, placed upon an imperfectly insulating, or an imperfectly conducting plane, for the purpose of collecting weak and scattered electricity, was called a *condenser* by Mr. Volta. The reason of using an imperfectly conducting, or imperfectly insulating plane, is, that when the insulated condensing plate is placed upon it, the electricity will not pass from the latter to the former. In short, the following particulars should be attended to in the construction of this, Mr. Volta's, condenser. The metal plate should be about six inches in diameter, with the edge well rounded, and furnished with a varnished glass handle. The inferior plane must be of a very imperfectly conducting nature, such as dry marble, very dry and slightly varnished wood, a common piece of wood covered with oiled silk, or such like substance; but be its substance what it may, its surface must be very smooth, and such as to coincide as well as possible with the surface of the metal plate, *viz.* the receiving plate; on which account, if a marble slab be chosen for the inferior plane, it will be proper to fit the surface of the metal receiving plate to that of the marble, by grinding one against the other.

The apparatus, consisting of the above described two planes, being properly constructed, lay the receiving plate upon the other plane, connect the former with an atmospherical conductor, not much elevated above a house, or with the vapour of boiling water, or, in short, with any weak source of electricity, such as could not be discovered by any other means, and after a certain time lift the receiving plate from over the other plane, holding it by the glass handle, and present it to an electrometer, which will be caused to diverge sufficiently to ascertain the presence and the quality of the electricity. Sometimes the receiving plate will even be able to afford a spark. Yet, in several cases, the receiving plate is electrified so slightly, as not to occasion the divergency of the most delicate electrometer. A contrivance of Mr. Cavallo, which is described in his Treatise on Electricity, (fourth edition, vol. ii. p. 265) rendered this weak state of electricity capable of affecting the electrometer in a very sensible degree. His description of this contrivance is as follows:

"I naturally thought that, for the same reason which enabled the condensing plate of Mr. Volta's apparatus, to manifest such small degrees of electricity as could not otherwise be observed, another smaller plate, or small condensing apparatus, might be employed to collect and to render sensible the weak electricity of the large metal plate. Accordingly, I constructed a small plate of about the size of a shilling, having a glass handle covered with sealing-wax; and when the large metal plate seemed to be electrified so weakly as not to affect an electrometer sensibly, I placed the small plate upon the inferior plane, and touched it with the edge of the large plate; then, after removing the large plate, I took up the small one from the plane, holding it by the extremity of the glass handle, and presented it to the electrometer, which generally was so much affected by it as to diverge to its utmost limits.

"In this manner I have often obtained electricity, more than sufficient to ascertain its quality, from a single stroke of the corner of an handkerchief; *viz.* the large plate being laid upon the proper plane, was stroked once with the handkerchief; then, being removed and presented to an electrometer, it appeared not electrified; but by touching the small plate with the edge of it, that small plate acquired thereby electricity sufficient to make an electrometer diverge."

With this condensing apparatus Mr. Volta, and other philosophers, made several discoveries; yet the use of it was not always attended with the desired effect, which was principally owing to the changeable nature of the semiconducting plane, upon which the receiving-plate was placed; it being difficult to obtain, and much more difficult to preserve, such plane in a middling or semiconducting state; for sometimes it would carry off the electricity from the superimposed receiving plate, and at other times it was not of a conducting nature sufficient to enable the upper plate to condense the electricity. It, likewise, often happened that this plane would acquire some electricity either in consequence of the slightest friction, or by communication, which rendered the action of the upper plate quite equivocal. With a view to remove these inconveniences Mr. Cavallo contrived an instrument capable of answering the same purpose, but quite free from all the above-mentioned objections. The principle of this instrument is like that of Mr. Volta's condenser; excepting that the receiving plate does not touch the other plane, though it comes very near it, and it likewise opposes another plane to the other side of the receiving plate. Those planes are of metal, and by their not touching the receiving plate, enable the latter to act with certainty and without obstruction. Upon this principle, *viz.* of the two plates not actually touching, but approaching one another very nearly, the present electrical condensers are constructed, however they may have been varied in size, in name, and in shape. By the aid of these condensers various important discoveries have been made in electricity, and especially in that branch of it, which is called galvanism. The original description of this instrument of Mr. Cavallo, is in the 78th. vol. of the Philosophical Transactions, for the year 1788, from which we make the following extracts.

"The properties of this machine, which from its office may be called *a collector of electricity*, are first, that when connected with the atmosphere, the rain, or in short with any body which produces electricity slowly, or which contains that power in a very rarefied manner, it collects the electricity, and afterwards renders both the presence and quality of it manifest by communicating it to an electrometer. Secondly, this collecting power, by increasing the size of the instrument and especially by using a second or smaller instrument of the like sort to collect the electricity from the former, may be augmented to any degree. Thirdly, it is constructed, managed, and preserved with ease and certainty; and it never gives, nor can it give, an equivocal result, as I have proved experimentally, and as will appear by considering its construction."

"The figures 4 and 5, *Plate*, II. *Electricity*, exhibit this instrument, *viz. fig.* 4 shews the instrument in the state of collecting the electricity, and *fig.* 5 shews it in the state in which the collected electricity is to be rendered manifest. An electrometer is annexed. The letters of reference indicate the same parts in both figures. A B C D is a flat tin plate, thirteen inches long and eight inches broad; to the two shorter sides of which are soldered two tin tubes, AD and BC, which are open at both ends. DE and EF, are two glass sticks covered with sealing wax by means of heat, and not by dissolving the sealing wax in spirits. They are cemented in

the lower apertures of the tin tubes, and alſo in the wooden bottom of the frame or machine, at E and F, ſo that the tin plate, ABCD, is ſupported by thoſe glaſs ſticks in a vertical poſition, and is exceedingly well inſulated. GHILKM and NOPV, are two frames of wood, which being faſtened to the bottom boards, by means of braſs hinges, may be placed ſo as to ſtand in an upright poſition and parallel to the tin plate, as ſhewn in *fig.* 4. or they may be opened, and laid upon the table which ſupports the inſtrument, as ſhewn in *fig.* 5. The inward ſurfaces of thoſe frames from their middle upwards are covered with gilt paper, X, Y; but it would be better to cover them with tin plates, hammered very flat. When the lateral frames ſtand ſtraight up, they do not touch the tin plate; but they ſtand at about one-fifth part of an inch aſunder. They are alſo a little ſhorter than the tin plate, in order that they may not touch the tin tubes, AD, BC. In the middle of the upper part of each lateral frame is a ſmall flat piece of wood, S and T, with a braſs hook; the uſe of which is to hold up the frames without the danger of their falling down when not required, and at the ſame time it prevents their coming nearer to the tin plate than the proper limits. It is evident that when the inſtrument ſtands as ſhewn in *fig.* 4, the gilt ſurface of the paper, X, Y, which covers the inſide of the lateral frames ſtands contiguous and parallel to the tin plate."

"When the inſtrument is to be uſed, it muſt be placed upon a window, a table, or other convenient ſupport, a bottle electrometer is placed near it, and is connected, by means of a wire, with one of the tin tubes, AD, BC; and by another conducting communication the tin plate muſt be connected with the electrified ſubſtance, the electricity of which is required to be collected on the plate, ABCD: thus, for inſtance, if it be required to collect the electricity of the rain, or of the air, the inſtrument being placed near a window, a long wire muſt be put with one extremity into the aperture, A or B, of one of the tin tubes, and with the other extremity projecting out of the window. If it be required to collect the electricity produced by evaporation, a ſmall tin pan, having a wire or foot of about ſix inches in length, muſt be put upon one of the tin tubes; ſo that the pan may ſtand about two or three inches above the inſtrument. A lighted coal is then put into the pan, and a few drops of water poured upon it, will produce the deſired effect."

"The quantity of electricity, which the tin plate, ABCD, is capable of collecting, principally depends on three circumſtances, *viz.* 1ſt. On the diſtance between the tin-plate and the conducting lateral ſurfaces: the ſmaller that diſtance is, the greater being the collecting power; 2dly. On the ſize of the inſtrument; and 3dly, On the quantity of electricity poſſeſſed by the body from which it muſt be collected or taken away."

"I need not expatiate on the principle upon which the action of this inſtrument depends; this being the ſame as that of the electrophorus of Mr. Volta's condenſer, and of many other electrical experiments; namely, that a body has a much greater capacity for holding electricity, when its ſurface is contiguous to a conductor which can eaſily acquire the contrary electricity, than when it ſtands not in that ſituation."

Though this original condenſer, which, by way of diſtinction, its inventor called a collector, anſwers the purpoſe for which it was intended perfectly well; yet for the common run of experiments, its ſize may be diſpenſed with, as it takes up too much room on the table of an electrician. On this account, not only the ſize of the inſtrument has been reduced, but its ſhape alſo has been varied according to the fancy of almoſt every philoſophical inſtrument maker. For the ſake of ſimplification in the condenſers which are at preſent in general uſe, one conducting plane only is oppoſed to the receiving plate, which anſwers the purpoſe ſufficiently well; for if the electricity collected by the receiving plate happens to be too weak to affect the electrometer, a ſmaller condenſer may be uſed, which will condenſe the electricity of the former, &c.

The forms of the condenſers that are moſtly uſed at preſent, are repreſented in *figs.* 6, 7, 8, and 9. *Fig.* 6 exhibits a vertical ſection of the condenſer conſtructed by Mr. John Read of Knights-bridge; *a a* is a circular flat plate of braſs, about eight inches in diameter, ſtanding inſulated, by means of the glaſs ſtick *f*, on the wooden foot *g*; *gh* is a hollow braſs cylinder, terminating in the hollow braſs cone *e c d h*; and to this cone the flat perforated braſs plate *b c c b* is affixed. The glaſs ſtick *f*, which, by means of a braſs ferril, is faſtened to the plate *a a*, has its lower extremity cemented in a cylindrical piece of wood, and this piece of wood is fixed in the bottom *g*. Now it will be eaſily perceived, by inſpecting the figure, that the hollow cylinder *h g* may be moved up or down by ſliding it upon the cylindrical piece of wood; and that, by ſo doing, the plate *bccb* may be brought near to, or removed from the plate *a a*, which is the receiving plate of this condenſer; *i* is a milled-head ſcrew, which ſerves to fix the plate *b b* at a proper diſtance from *a a*, where a ſtop is made for that purpoſe; when *i* is looſened, the plate *b b*, with *c h g*, which is all one piece, falls in the ſituation repreſented in the figure, and in that ſtate an electrometer is put in contact with the plate *a a*, in order to manifeſt the electricity which *a a* condenſed whilſt *b c c b* ſtood near it.

Fig. 7 repreſents a condenſer of another form, as made by Mr. Cuthbertſon. This ſort of condenſer is both ſimple in its conſtruction, and commodious in practice; *a b* is a braſs plate of about 8 inches in diameter (the inſtrument being ſhewn in profile), which is ſcrewed tight into the wooden head *c*, which is cemented on the glaſs ſtick *d*, and this is cemented with its lower extremity into the wooden ſtand *e e* of the inſtrument; *f i* is a ſimilar plate of braſs, faſtened to the braſs head and pillar *g i*, the lower part of which turns round a pin at *h*, ſo that it may either ſtand upright, or it may be inclined after the manner of the dotted repreſentation *h m*. It is almoſt ſuperfluous to add, that *a b* is the receiving plate of this condenſer. *Fig.* 8 ſhews a front view of a condenſer of this ſort, placed cloſe to a gold leaf electrometer, furniſhed with a ſmaller condenſer, *viz.* ſuch as is repreſented by itſelf in *fig.* 9. The ſmall condenſer, *fig.* 9, is ſimilar to the one repreſented in *fig.* 7; ſaving that in *fig.* 9 the receiving plate is affixed to the cap of a gold-leaf electrometer; ſo that this apparatus, *viz. fig.* 9, may be uſed by itſelf in moſt experiments; but in certain caſes it will be neceſſary to employ the condenſer *fig.* 7 firſt, and afterwards the electricity may be farther condenſed by means of the apparatus *fig.* 9, as ſhewn in *fig.* 8.

There is an inſtrument contrived by Mr. Wilſon, which he calls "a compound electrical inſtrument for condenſing and doubling." But as the conſtruction, as well as the principal uſe, of that inſtrument properly belongs to another claſs of electrical inſtruments, its deſcription will be found in another part of this work. See DOUBLER, and MULTIPLIER *of electricity*.

CONDENSER *of forces*. This name was given by Mr. R. Prony to a contrivance for obtaining the greateſt poſſible effect from a firſt mover, the energy of which is ſubject to

augmentation or diminution within certain limits; and in general to vary at pleasure the resistance to which the effort of the first mover forms an equilibrium in any machine whatever, without changing any part of their construction. (Bulletin of the Philomathic Society at Paris, No. 83.)

The general problem in mechanics, of which this condenser is intended as a practical solution, is enunciated by Mr. Prony in the following terms:

"Any machine being constructed, to find, without making any change in the construction, a means of transmitting to it the action of the first mover, by fulfilling the following conditions; *viz.*"

"1. That it may be possible at pleasure, and with great speed and facility, to vary the resistance (against which the effort of the first mover must continually make an equilibrium) in limits of any required extent."

"2. That the resistance, being once regulated, shall be rigorously constant until the moment when it is thought proper to increase or diminish the same."

"3. That in the most sudden variations of which the effort of the first mover may be capable, the variation in velocity of the machine shall never undergo a solution of continuity."

Mr. Prony applies this solution of this problem to the dynamic effect of wind; but it will be easy to make the same general, when other first movers are used. *Fig.* 10 (*Plate* XVI. *Mechanics*) represents the plan, and *fig.* 11 the elevation of the machine. OO is the vertical arbor to which windmill-sails are adapted; *e e e e* is an assemblage of carpentry, of which one of the radii, O *e*, bears a curved piece, *b d*, of iron or steel: vertical axes of rotation *a a a*, being placed round the axis OO; they also divide the circumference in which they are found, into equal parts. Each of these axes carries a curve *a f*, of iron, steel, or copper; so situated, that when the wind acts upon the sails, the curve *b d* presses against one of the curves *a f*, and causes the vertical axis to which this last curve is affixed, to make a portion of a revolution. The curves *b d*, and *a f*, must be so disposed, that when *b d* ceases to press on one of the curves *a f*, it shall at the same instant begin to act upon the following curve: the number of axes which are provided with these curves, must be determined by the particular circumstances of each case, and it is also practicable to substitute, instead of *b d*, a portion of a toothed wheel having its centre in the axis OO, and to place portions of pinions instead of the curves *a f*; but the dispositions represented in the figure are preferable. Each of the axes *a a a a* (which are all fitted up alike, though, for the sake of clearness, only one of them has its apparatus represented in the drawing), carries upon it a drum or pulley, *t t r r*, on which is wound a cord that passes over a pulley *p*, and serves to support a weight Q, by means of the lever F G, upon which this weight may be slided and fastened at different distances from the point of motion G. The same axes, *a*, *a*, pass through the pinions *q*, *q*, to which they are not fixed; but these pinions carry clicks or ratchets, which bear against *r r*; so that when the weight Q tends to rise, the ratchet gives way, and no other effect is produced on the pinion *q q*, either by the motion of the axis or of the drum *t t r r*, excepting that which causes the ascent of the weight *q q*. But the instant that the curve, or tooth *b d*, ceases to bear against one of the curves *a f*, after having caused the corresponding weight Q to rise, that weight Q tends to re-descend, and then the toothed wheel *r r* acts against the ratchet, so that Q cannot descend without turning the pinion *q q* along with the drum *t t r r*. The pinion *q q* takes in the wheel *a b*, from the motion of which the useful effect of the machine immediately results; so that the effect of the descent of one of the weights Q is to solicit the wheel A B to motion, or to continue the motion in concurrence with all the other weights Q, which descend at the same time. This wheel, A B, carries beneath it oblique or bevelled teeth, G D, which take in a like wheel, C E, and cause the buckets at S to rise.

From the preceding description, it is seen that the machine being supposed to start from a state of repose, the wind will at first raise a number of weights, Q, sufficient to put the machine into motion, and will continue to raise new weights, whilst those before raised are fallen, so that the motion once impressed will be continued.

Among the numerous advantages of this new mechanism, the following may be remarked:

1. No violent shock can take place in any part of the mechanism. 2. The useful effect being proportioned to the number of weights Q, which descend at the same time, this effect will increase in proportion as the wind becomes stronger, and causes the sails to turn with greater velocity. 3. The weights, Q, being moveable along the levers F G, it will always be very easy to place them in such a manner as to obtain that ratio of the effort of the first mover to the resistance, which will produce the maximum of effect. 4. From this property it results, that advantage may be taken of the weakest breezes of wind, and to obtain a certain product in circumstances under which all other windmills are in a state of absolute inactivity. This advantage is of great importance, particularly with regard to agriculture: the windmills employed for watering lands, are sometimes inactive for several days, and this inconvenience is more particularly felt in times of drought. A machine capable of moving with the slightest breeze, must, therefore, offer the most valuable advantages.

Conductors

CONDUCTORS. In two important branches of natural philosophy, a marked distinction has been observed between the various known bodies of the earth; and upon the peculiar properties of the two different classes of bodies, which are discriminated from each other by the above-mentioned distinction, numerous phenomena, of consequence to the human species, are absolutely depending. The two branches, of natural philosophy, above alluded to, are the science of electricity and the subject of heat. In electricity, if an excited piece of glass, or an electrified conductor, be touched with the extremity of a stick of sealing-wax, which a man holds by its other extremity; or if it be touched with the extremity of a silk string, the electric power will not be dissipated; but if the electrified body be touched with the extremity of a rod of iron or brass, held in a manner similar to the stick of sealing-wax, the electric power will be instantly dissipated; *viz.* it will pass through the metallic rod, and through the person that holds it, &c. Hence it evidently appears, that iron or brass will permit the transition of the electric power through its substance; whereas sealing-wax or silk will not permit it. Therefore, iron, brass, and all those substances through which the electric power can be transmitted, are called *conductors of electricity;* and all those substances, which, like the sealing-wax or the silk, will not permit the passage of the electric power, are called *non-conductors of electricity.*

A similar distinction has been remarked in the subject of heat and cold. Take a small piece of charcoal, make it red hot at one end, and in that state it will be found that a person may hold it with his fingers within about a quarter of an inch of the red hot extremity, without feeling any unpleasant degree of heat; but if an iron rod as thick as the charcoal be rendered red hot at one end, a person will not be able to hold it within less than four or five inches, at least, of that end; and such is the case with all metallic bodies, as well as with some other substances; which shews that heat will pass through certain bodies much more easily than through others. Hence those bodies which, like the iron rod, will easily transmit the heat through their substance, are called *conductors of heat;* and those which will convey it with great difficulty, are called *non-conductors of heat.* It must be observed, however, that though heat will pass incomparably more easily through certain bodies than through others; yet there are no bodies that are known to be either perfect conductors or perfect non-conductors of heat. And indeed, the like observation, though in a much more limited manner, may be made with respect to the conductors of electricity.

In magnetism also, the name of *conductor of that power* has been given to a single substance, namely, to soft iron; but the peculiar nature of iron in that respect, or rather the passage of the magnetic power, will be explained under the article MAGNETISM. We shall now in an orderly manner state the various particulars which have been ascertained with respect to the above-mentioned two classes of bodies; *viz.* first with respect to electricity, and then with respect to heat.

CONDUCTORS *of Electricity.* In endeavouring to point out the true nature of electrical conductors, it becomes necessary to give a list likewise of the non-conductors of that power, since these two classes of bodies gradually approach each other, in proportion as they are less perfect of their kind, as far as certain substances, which seem to stand in an intermediate state between conductors and non-conductors, so as to participate of both. Glass, sealing-wax, amber,

silk, and several other bodies, which, by means of friction with a dry and clean hand, are capable of being excited, so as to exhibit electrical phenomena, are called *electrics;* and these identical bodies have been found to be non-conductors of electricity; hence *electrics* and *non conductors* mean the very same class of bodies. In the same manner it has been found, that those bodies, which will easily transmit the electric fluid through their substance, cannot be excited in the above-mentioned manner; hence *conductors* and *non-electrics* do also denote the same bodies.

Strictly speaking, as we have already hinted above, there is no substance which may be called a perfect conductor or a perfect non conductor of electricity; the electric power finding some resistance in its passage through the best conductors, and being in some degree capable of passing through the best electrics, at least under certain circumstances. The following lists contain the conductors and the electrics, or, which is the same thing, the non-electrics and the non-conductors. They are disposed in the order of their perfection; that is, the best conductors and the best electrics are placed at the heads of their respective lists; and those which participate of both, meaning those which are partly electrics and partly conductors, will be found towards the end of each list. In this, however, no great accuracy must be expected; first, because a very accurate discrimination is impracticable when substances are expressed under general denominations; and, secondly, because the precise degree of conducting or non-conducting power in most substances cannot be determined on account of their fluctuating nature.

Conductors.

Gold.
Silver.
Copper.
Platina.
Brass.
Iron.
Tin.
Mercury.
Lead.
Semi-metals.
Metallic ores; of which the best are those which contain a greater proportion of metallic parts, and nearest to a reguline state.
Charcoal, either of animal or vegetable substances. The conducting power of charcoal is very equivocal; for some pieces of it will hardly conduct at all, and others will suffer the passage of the electric fluid over their surface only, and not through their substance. The reason of this difference is not quite understood; but it seems owing to the degree of heat that is applied in the process of making them. See Priestley's second volume of Observations on different Kinds of Air, sect. xiv.
Animal fluids.
Acids.
Saline substances.
Hot water.
Cold water.
Salt water.
All other liquids excepting oils.
Red-hot glass.
Melted resin.
Flame, or the effluvia of flaming bodies.
Ice and snow; but not below a certain temperature; for Mr. Achard, at Berlin, in January 1776, observed that frozen water, or ice, at the temperature of 28° below 0° of Reaumur's scale (equal to —13 of Fahrenheit's) was become an electric. He tried his experiments in the open air, where he found that a rod of ice two feet in length, and two inches thick, was a very imperfect conductor at the temperature of 6° below 0° of Reaumur's thermometer, and that it would not conduct in the least at 20° below 0°. By whirling a spheroid of ice in a proper machine, he even electrified the prime conductor, so as to attract, repel, give sparks, &c., like any other electric.
Most saline substances, of which the metallic salts are the best.
Earthy and stony substances, of which the hardest are the worst.
Glass filled with boiling water, as mentioned by Kinnersley.
Smoke.
Vapour or steam of boiling water.
All compounds, in which different proportions of the above-mentioned substances enter, are conductors in different degrees.
An imperfect vacuum, or the absence of air produced by the action of an air-pump. But a perfect Torricellian vacuum is not a conductor of electricity. Mr. Walsh, assisted by Mr. De Luc, having made a double barometer, in which the mercury had been accurately boiled, so as to expel all the air from the tube, found that the vacuum in the arched part of this double barometer was not a conductor of electricity, nor any electric light could be seen in it. (Priestley's Experiments and Observations on Elastic Fluids, vol. i.) This remarkable discovery was afterwards confirmed by the experiments of Mr. Morgan. (Phil. Trans. vol. lxxv.)

Electrics.

Glass, and all vitrifications, even those of metals.
All gems, of which the most transparent are generally the best.
All resins and resinous compounds.
Amber.
Sulphur.
Baked wood, if not suffered to imbibe moisture.
All bituminous substances.
Wax.
Silk.
Cotton.
All dry and external animal substances, as feathers, wool, hair, &c.
Paper.
White sugar and sugar-candy.
Air, and other gases.
Oils.
Dry and complete metallic oxides.
The ashes of animal and vegetable substances.
All dry vegetable substances.
All hard stones, of which the hardest are the best.
Soft stones when heated, according to Delaval.
Powders not metallic, according to Delaval.
Ice, at the temperature of —13° of Fahrenheit's thermometer, according to Achard.
According to Mr. Walsh's, and Mr. Morgan's experiments, the Torricellian vacuum ought to be placed at the head of the list; but the singular nature of a vacuum, though a non-conductor, will hardly entitle it to the name of an electric. We must, however, refer all farther observations, respecting *electrics*, to the article of that denomination.

the above list having been inserted in this place merely to elucidate the nature of conductors.

Thus far we have stated the number of conductors, and their gradation, with respect to common electricity; but that lately discovered branch of this science, which is at present assiduously cultivated under the title of Galvanism, has pointed out a peculiar arrangement of conductors with respect to the order of their capability of conducting that power which affect the limbs of a prepared animal, and of conveying the power of a galvanic, or rather a Voltaic, battery. See the article GALVANISM. Concerning the former of these powers, we transcribe a list, followed by a few remarks, from Cavallo's Treatise on Electricity, 4th ed. vol. iii. p. 20; and with respect to the latter, we subjoin an abridged extract from a paper of Erman, in the Annales de Chimié, Feb. 1807.

Conductors of Animal Electricity, according to Dr. Lind's and Mr. Cavallo's experiments, which however are arranged with diffidence by the latter, considering the difficulty of making the arrangement, and that, in this branch of electricity, the metals do not seem to act merely as conductors—The list begins with the best.

"Malleable platina.
Silver.
Gold.
Quickfilver.
Copper.
Brass.
Tin.
Lead.
Iron.
The human body.
Salt water.
Fresh water."

"The metallic ores are not so good conductors as the purified metals themselves, and their conducting power is various according to the nature of the ores, but even the metallic salts are tolerably good conductors.

"It is very remarkable, that the flame of tallow candle, which is a good conductor of common electricity, will not conduct the animal electricity, when placed in a short interruption made in the circuit of communication. Charcoal, placed in the same situation as the flame of the candle, was also found to be a non-conductor, except when it was actually burning, in which state it conducted tolerably well; but Mr. Volta says that he has found some pieces of charcoal that acted as well as the metals. Dr. Valli observed, that human bodies are not all equally good conductors. Out of four persons in a company, he found that when two of them formed the circuit of communication between the nerve and the muscles of a frog, the motions took place very readily. When a third person formed the circuit, the motions were very weak; but that when the fourth person formed the communication no motion took place. This experiment, he adds, was often repeated with the same success. The effect, however, may be owing to the different dryness of the skin. Vitriolic acid, and what is very remarkable, alcohol, appear to conduct this property rather better than water.

"The arteries and the veins are not so good conductors as the nerves; for when a blood-vessel forms part of the circuit of communication, the contractions will take place only when nervous ramifications are adhering to it, and if these be carefully separated, the motion will not take place. The same thing may be said of the tendons, the bones, and the membranes: for when either of those parts is separated from the body, and is introduced in the circle of communication between the muscles and nerves of a prepared frog, no motion will ensue, excepting, indeed, when those parts are full of moisture, and are in immediate contact with the nerve of a prepared frog. Dry nerves are not conductors of animal electricity. Dr. Valli found that the internal substance of a nerve conducts much better than its external, or coat."

Silver and zinc, professor Aldini says, will produce contractions in the muscles of a frog, many hours after it has become insensible to the action of either of them, separately used.

Mr. Erman, in his paper on two new classes of galvanic conductors, says that the bodies which may be applied to the poles of a galvanic pile are, I. *Non conductors*. II. *Conductors*. The conductors are either *perfect* or *imperfect*; and the imperfect conductors are so, either with respect to *both poles*, or with respect to *one of the poles* of a galvanic battery.

I. The *perfect non conductors* prevent the communication of the power of both poles effectually; and such are glass, resins, ice, and the vapour of water, sulphur and its flame, amber, but not its flame.

II. The *perfect conductors*, which discharge both poles completely, are the metals, and all in the same degree.

The *imperfect conductors of both poles*. These, though capable of forming the galvanic circuit, exhibit in their extent effects of two different kinds. Fluid water and bodies impregnated with water are of this nature.

The *imperfect conductors of the positive pole only*. These are incapable of forming the galvanic circuit; for when interposed between the two poles of the pile, they insulate the negative power and conduct the positive; whence it follows, that the negative becomes charged, whereas the positive is conducted. The flame of hydrogen gas, and the flame of the hydrocarbonated bodies, have this property.

Lastly, *the imperfect conductors of the negative pole only* insulate the power of the positive, and conduct the power of the negative pole. Of this sort are the flame of phosphorus and of alkaline soaps.

There now remain two other particulars, which demand our examination with respect to the conductors of electricity. These are the method of ascertaining their peculiar degrees of conducting power, and their uses. The simplest method of determining whether any given body be a conductor or not, is to affix an electrometer to the prime conductor of an electrical machine, and when the machine is in action, and of course the electrometer is diverging, to touch the prime conductor with one extremity of the given body, which the operator holds in his hand by the other extremity; for if, in so doing, the electrometer collapses, the body in question is a conductor; but if the electrometer continues to diverge, that body is a non-conductor. Its degree of conducting power may also be, in great measure, estimated from the quickness with which the electrometer loses its divergency. In the performance of this experiment, the operator should take care that the electric fluid does not run over the surface of the body under trial to the hand that holds it, which generally takes place when the machine acts powerfully, and the body in question is not much extended. In this case, it becomes proper to stop the revolution of the glass globe or cylinder, when the body is to be put in contact with the prime conductor. But if the body be very small, it will be sufficient to use a simple electrometer only, which may be easily caused to diverge by means of an excited stick of sealing-wax, and may then be touched with the body in question. Yet all this is not

sufficient to discriminate the peculiar powers of substances that are of the same class, such as the various metallic substances, the different stones, &c. And for this purpose various other means may be adopted, according to the nature of the bodies under examination. The best way of determining the peculiar conducting powers of metallic substances, is to have wires of the different metals drawn through the same hole, so as to be precisely of the same diameter, and then melt them by the discharge of a battery; *viz.* take a wire, of about one-fiftieth of an inch in diameter, and connect it with the outside of a battery, containing at least thirty square feet of coated surface, and connect the other extremity of the wire with one branch of the discharging rod. Then, when the battery is charged, touch the wires which proceed from the inside of it with the other branch of the discharging rod, which will force the explosion to pass through the wire that has been interposed between the battery and the discharging rod, generally melting a greater or a smaller part of it, according to the nature of the metal. Thus by repeating the experiment successively with wires of the same length and diameter, but of different metallic substances; charging the battery constantly to the same height, which may be easily accomplished by means of a quadrant electrometer; and measuring the length of each wire that has been melted by the explosion; their various conducting powers may be ascertained; observing that the worst conductors are more easily melted, and *vice versâ*. Mr. Henley found that the same charge melted 4 inches of gold wire, 6 of brass, 8 of silvered copper, 10 of silver, and rather more than 10 of iron. In melting wires of a considerable length, as for instance two or three feet, it often happens that the force of the explosion barely renders it red hot, without actually melting it. In this case, it is curious to observe that the redness appears first on that extremity of the wire which communicates with the positive side of the battery, and thence proceeds towards the other end of the wire, which shews an ocular proof of the theory of a single electric fluid; the wire, however, is not rendered red hot at one extremity before the other, in consequence of the progressive motion of the electric fluid through it, but because that fluid loses some of its impetus in going through the wire, so that the wire suffers the greatest effect of the shock on that end which the electric fluid enters; in consequence of which, that same end will be rendered red hot much sooner, and in a greater degree, than those parts which are more remote from it.

When the conducting powers of different fluids are to be ascertained, the best method of performing the experiment is to fill very narrow glass tubes, such as are used for spirit thermometers, with the fluids in question, introducing a pin at each end of the tubes; and to present them successively to the prime conductor, after the manner already described. For other kinds of bodies other methods may be adopted for ascertaining their conducting powers. These, however, need not be particularly described; first, because they may be easily derived from those that have been described above; and, secondly, because they must be varied according to the nature of the bodies in question. After all, it must be acknowledged, that the metals excepted, no very great degree of accuracy can be expected with other substances; since the fluctuation of their conducting powers arises from a variety of slight, and almost imperceptible differences, such as the difference of temperature, of moisture, of admixture with other substances, &c. Thus, glass itself becomes a conductor, when heated to a certain degree; and the very same body will conduct more or less readily, even by being placed nearer to or farther from certain other bodies.

In considering the conducting power of natural bodies, one may naturally ask, whence does that property arise; or how is it, that certain bodies will, whilst others will not, conduct the electric power? The present state of knowledge, however, does not afford a satisfactory answer to this question. Various suppositions have been offered by the late Dr. Priestley and others; but as they are insufficient for the explanation of the phenomena, we shall not attempt to state them in this place.

The uses of conductors are remarkable and extensive, though they are not yet fully ascertained to the entire satisfaction of the speculative philosopher. In the first place, the science of electricity, or the existence of the electric power, would be absolutely unknown, were it not for the difference of conducting and non-conducting bodies; for otherwise the electric fluid which is manifested to us, and operates merely by its passage from one body to another, could neither be confined nor accumulated in any place; in consequence of which, its uniform dispersion throughout the universe would remain inactive and unperceived. But the movements of conducting and non-conducting bodies in the world, their contact, or even their approach without any actual contact, condenses the electric fluid in one place, and rarefies it in another; and this takes place between the clouds and the earth, &c. By the change of their states of existence, some bodies absorb from other bodies; and others deposit upon other bodies considerable quantities of electric fluid. Thus, a perpetual and ample circulation of that fluid is continually kept up amongst all the substances of the terraqueous globe, whence thunder and lightning, vaporization, and probably several other important operations of nature, are derived. In order to understand the action of conductors when opposed to each other, see the nature of electric atmospheres under the article ELECTRICITY.

The greatest advantage which mankind have derived from the knowledge of the present subject, is the adoption of a conductor for the preservation of buildings and vessels against the dire effects of lightning. The identity of electricity and lightning proved by Dr. Franklin, and his subsequent introduction of conductors for preserving buildings, form two of the grandest discoveries of the last century. It was proposed by the above-mentioned philosopher to raise a metallic conductor some feet above the highest part of the building, to continue the same down along the outside of the wall, and below it, deep into the earth, or, which is preferable, to connect it with some well or drain. By these means the house would have little to apprehend from a stroke of lightning; for, since an electrified body is well known to strike the nearest and best conductors that may happen to be in its way, it is evident that the conductor situated in the abovementioned manner, being of metal, and higher than any part of the building, would naturally be struck by the lightning in preference to any other part, and would conduct it to the ground, without any damage to the building.

This reasonable proposal was no sooner offered by the sagacious Franklin, than it was adopted in America, in Europe, and elsewhere. Numerous facts soon proved the usefulness of such conductors, and extended its adoptions by shewing that several houses, which before had been repeatedly struck by the lightning, escaped unhurt after the application of the conductor; that, in many places, the conductors of houses were actually struck by the lightning, which melted them about their extremities, yet the houses themselves received no injury; and so forth.

Though the conductors were instantly adopted, yet their

most useful form, especially with respect to their upper termination, has been much controverted; and it is but lately that the true state of the question has been elucidated. The question was, whether the conductors should terminate in a point, according to Dr. Franklin's original proposal, or in a ball. Mr. B. Wilson exhibited some experiments, in which a point was struck at a greater distance than a ball; whence he concluded, that as the point would attract the lightning from a greater distance, a blunt termination ought to be preferred, since, in certain cases, it would avoid a stroke of lightning, which the pointed termination would not. (Phil. Trans. for 1778). Mr. Nairne, on the other hand, shewed some experiments, in which a ball was struck in preference to a point. And this indeed is confirmed by a great variety of other experiments. In short, a pointed conductor will draw the electric fluid from an incomparably greater distance than a blunt one; but it will draw that fluid gradually, in a stream, or silent manner; whereas the blunt termination will receive it in a full spark, or at once; hence a pointed conductor will tend to diminish the quantity of electricity in a cloud, previous to its coming too near, and thus it may protect a greater extent of building than a conductor with a blunt termination, since the object of fixing a conductor to a house is to protect the house from the effects of lightning, and not the conductor from transmitting the matter of the lightning.

Upon the whole, considering the immense quantity of electricity in a thunder cloud, and the little difference between the action of a blunt or a sharp conductor with respect to that quantity, the difference of those terminations seems to be of less consequence than it was apprehended in the fervour of the dispute. After all the experiments and the discussions made for the purpose, "A conductor," Mr. Cavallo observes, "to guard a building, as it is now commonly used in consequence of several considerations and experiments, should consist of one iron rod, (copper would do much better, it being a more perfect conductor of electricity, and at the same time not being subject to contract rust so soon as iron), about three quarters of an inch thick, fastened to the wall of the building, not by iron cramps, but by wooden ones. If the conductor were quite detached from the building, and supported by wooden posts at the distance of one or two feet from the wall, it would be much better for common edifices; but it is more particularly advisable for powder-magazines, powder-mills, and all such buildings as contain combustibles ready to take fire. The upper end of the conductor should be terminated in a pyramidal form, with the edges, as well as the point very sharp; and if the conductor be of iron, it should be gilt or painted for the length of one or two feet. This sharp end should be elevated above the highest part of the building, (as above a stack of chimnies, to which it may be fastened), at least five or six feet. The lower end of the conductor should be driven five or six feet into the ground, and in a direction leading from the foundations; or it would be better to connect it with the nearest piece of water, if any be at hand. If this conductor, on account of the difficulty of adapting it to the form of the building, cannot conveniently be made of one rod, then care should be taken, that where the pieces meet they be made to come in as perfect a contact with one another as possible; for the electricity finds considerable obstruction where the conductor is interrupted. For an edifice of a moderate size, one conductor, in the manner already described, is perhaps sufficient; but, in order to secure a large building from sustaining any damage by lightning, there should be two, three, or more conductors, in proportion to the extent of the building.

"In ships a chain has often been used for this purpose, which, on account of its pliableness, has been found very convenient, and easy to be managed among the rigging of the vessel; but as the electricity finds a great obstruction in going through the several links, for which reason chains have been actually broken by the lightning, so their use has now been almost entirely laid aside; and in their stead, copper wires, a little thicker than a goose-quill, have been substituted, and have been found to answer very well. One of those wires should be elevated two or three feet above the highest mast in the vessel; this should be continued down the mast, as far as the deck, where, by bending, it should be adapted to the surface of those parts, over which it may most conveniently be placed, and, by continuing it down the side of the vessel, it should be always made to communicate with the water of the sea."

Another precaution must be added to the above directions, which is, that a communication should be made between the conductor, and all other pretty large pieces of metal in the building, such as leaden spouts, large iron clamps, &c.; for otherwise a lateral explosion may take place between those detached pieces of metal, at the time that the lightning is conveyed by the conductor, and thence the building may receive some damage, though not in a very great degree, unless indeed in case of powder mills and powder-magazines. See LATERAL EXPLOSION.

It is owing to this circumstance, that some buildings furnished with a conductor or two, are said to have been struck and to have been damaged by a stroke of lightning. See Phil. Trans. vol. lxxii.

The size of the conductor, as recommended in the preceding paragraphs, has by some been thought too small for the purpose; and an instance is recorded of a conductor of iron, four inches wide, and half an inch thick, which is said to have been made red hot by a stroke of lightning. But with respect to this remark, we shall briefly observe, that should any person think that the conductor, as directed above, is not large enough, the enlargement of its size is attended with no other inconvenience than an increase of expence. However, though a conductor be made red hot, and even melted by a stroke of lightning, yet it will effectually convey that stroke of lightning to the ground without any material injury to the building, as has been sufficiently proved by experiments with artificial electricity, as well as with cases of conductors partly melted by the lightning.

CONDUCTORS *of heat.* When a congeries of bodies remains long in a given degree of temperature, these bodies will all acquire the same apparent degree of heat; that is, the thermometer placed in contact with any of them, will rise to the same degree; and in this case of equilibrium there is no reason to believe that any heat, or of caloric, passes from one body to another; but if a body, at a certain temperature, be placed amongst bodies of a different temperature, the caloric will, in this case, be communicated from the former to the latter, or *vice versâ;* according as the temperature of the former is higher or lower than that of the latter. This communication or passage of heat from one body to another, is made either by *contact* or by *radiation.*—*By contact,* when the bodies, which are contiguous to the hotter one, are progressively heated; *viz.* the nearest first, and then those which are farther off, without any interruption; as when a red-hot piece of iron is placed amongst other pieces of colder iron, the heat is gradually communicated from the red hot one to the others.—*By radiation,* when the heat from a hot body passes through a vacuum, or through transparent bodies, which are not heated by it, yet it elevates the temperature of bodies placed at some distance. Thus, the solar heat radiates freely through

air, glass, water, &c., and heats opaque bodies without sensibly affecting the transparent bodies through which it passes. Thus also, a thermometer suspended under the exhausted receiver of an air-pump, or in the Torricellian vacuum, continues to vary its temperature with that of the surrounding bodies.

In the communication of heat from one body to another, when a third body is interposed, it has been observed that the transition of heat is much quicker when certain bodies are interposed, than when other bodies are placed between; but there are no bodies known which prevent that transition effectually; hence the bodies of the universe are distinguished into more or less perfect conductors of heat, but they afford no instance of a perfect non-conductor.

The transmission of heat from a solid at a higher degree of temperature, to another at a lower one, in a given time, is nearly proportional to the difference of their temperatures. But the velocity with which heat is propagated through the substance of different bodies, varies considerably according to the nature of those bodies. In general, metallic bodies are the best conductors of heat; stones, or hard earthy bodies come next; then the vitreous substances, and the resinous. Dry animal parts, excepting bones, and especially dry and light vegetable bodies, are bad conductors of heat. The conducting power of liquids is of a particular nature, which will be mentioned presently. But the different bodies of the same class differ considerably in conducting power. Thus the metals possess it in different degrees, and their proportional powers were thus estimated by Dr. Ingenhousz. He procured equal cylinders of several metallic substances, and having coated them with wax, he plunged their extremities in hot water, and judged of the conducting power of each, by the length of the wax-coating that was melted. The result of these experiments is expressed in the following list, which commences with the best conductors. Journ. de Phys. 1789, p. 68.

Silver.
Gold.
Copper. } nearly equal.
Tin. }
Platina.
Iron. } much inferior to the others.
Steel. }
Lead.

In the same paper, the proportional conducting powers of three fluids are stated in the following manner:

	Equal bulks.	Equal weights.
Water	1.	1.
Mercury	2.	4.8
Linseed oil	1.111	1.085

The conducting power of the same body does not remain invariably the same in all circumstances; but it differs, according as the body changes its state of existence, so that the conducting power of a body in a solid state is different from that of the same body in a fluid state. And at the time of changing its state of existence, the conducting power in most cases ceases altogether. Thus, at the temperature of 60°, sulphur is a conductor; but when heated to 212°, at which point it melts and becomes volatile, it is no longer a conductor. Thus also, ice conducts at the temperature of 20°, or at any other temperature below the freezing point, which is 32°; but at that point it ceases to be a conductor, because the heat which may be communicated to it is absorbed as an ingredient necessary to its fluid state, which it assumes at, or little above, that point.

Rarefaction or condensation alters the conducting powers of several bodies. Yet the rarefaction of air is by no means accompanied with a proportionate diminution of its conducting power.

Professor Pictet supposes that heat ascends within solid bodies more readily than it descends; *viz.* that in communicating heat to a solid body by the lateral application of a hotter body, the upper parts of the former are heated sooner than the lower. This effect, however, may with propriety be attributed to the ascending current of heated air which rises along the surface of the body, and causes colder air to approach the lower part of the body; hence the heat is continually carried upwards.

The conducting power of a body changes likewise, in consequence of an alteration of the surface; so that polish and figure are likewise concerned in the reception as well as in the propagation of heat. These particulars, however, together with the reflection and refraction of heat, from the surface or through the substance of bodies, will, with more propriety, be explained under the article HEAT.

Fluids are, upon the whole, very imperfect conductors of heat, and Count Rumford was led, by his experiments, to conclude that heat is not at all propagated through them by contact, as it is in solids. (See Rumford's paper on the Conducting Property of Fluid, &c. Phil. Transf. 1805.). Whatever permits or promotes the motion of the particles of a fluid, contributes to the propagation of heat;—whatever obstructs that motion, retards the propagation of heat through them. The particles of air which come in contact with an heated body, being thereby heated and rarefied, become specifically lighter than the surrounding air, and of course ascend; other air then comes in contact with the heated body, and this also being heated is caused to ascend, and so forth. Thus is heat conveyed from the original hot body, by the air, to a distance from it; but if that motion of the air be obstructed, as by the interposition of partitions of paper, wool, cotton, furs, and the like, then the communication of heat is prevented more or less effectually. It is principally on this account, that furs, feathers, eider down, cotton, and other similar things, form warm coverings; *viz.* because, by preventing in great measure the motion of the air between their filaments, they prevent at the same time the dissipation of heat.

The like observations are applicable to water, and perhaps to all other fluids. When a vessel full of water is set upon the fire, the particles of water that are close to the bottom of the vessel are first heated and rarefied; in consequence of which they ascend, and other colder particles take their place, which, being heated, likewise ascend, and so on. If the fire be applied to the upper part of the water, the fluid will not be heated, or at most it will in a very slight degree. Count Rumford (see his 7th Essay) confined a piece of ice at the bottom of a pretty tall glass vessel full of water nearly boiling, and noted the time it took up to melt the ice. The experiment then was repeated with this difference, *viz.* that a similar piece of ice was placed on the surface of the hot water, instead of the bottom. It was found that the ice melted more than eight times quicker in this last situation than in the former. The result of this remarkable experiment is explained in the following manner. When the ice swims on the surface of the hot water, the particles of the latter, that are contiguous to the ice, being cooled by it, descend, and other hot particles of water take their place, which deposit their heat upon the ice, and, being thereby rendered specifically heavier than the next particles of watert also descend, and so forth. But when the ice is confined a,

the bottom of the veffel, the particles of hot water which come firft in contact with it, are cooled, and are rendered fpecifically heavier, in confequence of which they remain in their place, and no motion will take place within the water; hence the ice is not melted nearly fo readily as in the former fituation. Now count Rumford contends that it is by means of the above-mentioned motion only that heat is propagated through fluids, and not otherwife. This conclufion was no fooner publifhed to the fcientific world, than it was oppofed in an able manner by very fkilful philofophers. See Dalton's paper. Nich. Journ. vol. iv. p. 75. Traill's paper, ibid. for 1805, p. 133: and Murray's paper, ibid. vol. i. From thefe papers we fhall make the following abridged extracts, which feem neceffary for the elucidation of the fubject; and in the firft place we fhall ftate Mr. Murray's experiments.

Into a glafs cylindrical veffel water was poured, till it covered the bulb of a thermometer; its temperature was 46°, which was likewife the temperature of the air of the room. One ounce of olive oil, heated to 140°, was poured on a fmall piece of cord, fufpended on the furface of the water, and the cord was flowly withdrawn. Any motion of the water was thus avoided. In the courfe of a minute the thermometer began to rife flowly; in five minutes from the commencement of the experiment, it had rifen 4°, in ten minutes $6\frac{1}{2}$°, in fifteen minutes 8°. It then became ftationary, and continued fo for feven minutes, before it began to fall. Its defcent was flow. This experiment was repeated with a hot metallic ball (inftead of oil) immerfed in the water above the thermometer, and it was attended with a fimilar effect.

From thefe refults the conclufion might feem juft, that the fluid muft poffefs a conducting power. Yet this is rendered doubtful by the circumftance, that in all experiments of this kind, a quantity of caloric muft be conveyed by the fides of the veffel. In order to avoid this fource of error, Mr. Murray employed a veffel of ice. But water could not be ufed in this cafe, becaufe that fluid expands from 40° to 32°; therefore oil and mercury were ufed.

A quantity of almond oil was poured into the ice veffel, fo as to cover the bulb of the thermometer a quarter of an inch. A fmall cylindrical iron cup, two inches in diameter, and having a flat bottom, capable of holding two ounces by meafure, was fufpended fo as merely to touch the furface of the oil, and was filled with boiling water. At the beginning of the experiment, the thermometer ftood at 32°. In a minute and a half it had rifen to $32\frac{3}{4}$°, in three minutes to $34\frac{1}{2}$°, in five minutes to $36\frac{1}{4}$°, in feven minutes to $37\frac{1}{2}$°. At this point it became ftationary, having rifen $5\frac{1}{2}$° in feven minutes. The temperature of the water in the cup had in this time fallen to 96°. The thermometer, after remaining ftationary at $37\frac{1}{2}$° for fix minutes, began to fall, and it continued to defcend at the rate nearly of a degree in a minute and a half, till it returned to 32°. The experiment was repeated with this variation, *viz.* that the thermometer was placed lower, fo that half an inch of oil ftood over its bulb. It was alfo repeated with mercury inftead of oil. But in both cafes the refults were fimilar to that of the firft experiment.

"This rife," Mr. Murray fays, "it appears to me impoffible to afcribe to any other caufe than to a power in the fluid to conduct caloric. Thus it is evident, that the fides of the veffel could not convey to the fluid in contact with the bulb of the thermometer any part of the caloric it received. Ice, in common with any other folid, may, at temperatures below its melting point, conduct caloric; but as it cannot poffibly exift with a temperature above 32°, it cannot communicate any temperature above that to a fluid in contact with it, and confequently it could not contribute in the above experiment to raife the thermometer above that temperature. Caloric does not radiate through tranfparent fluids, and it cannot even be fuppofed capable of paffing by radiation through an opaque fluid as mercury.

If it be proved that oil and mercury are capable of conducting caloric, it will be admitted as fufficiently probable, that other fluids may have a fimilar power. Of thefe two, mercury, it is probable from thefe experiments, is the beft conductor, as the rife of the thermometer took place in it much more rapidly than in the oil."

Dr. Traill's experiments for afcertaining the conducting powers of divers fluids, were performed in the following manner.

A cylindrical veffel was turned out of wood, having its fides half an inch thick, its height four inches and its diameter two. It has a moveable wooden top or cover, perforated with a hole in its centre, a little more than an inch in diameter, into which an iron cylinder, of one inch in diameter, could be eafily introduced. This cylinder is fupported by a flight flanch, or fhoulder-piece, and can be taken up by means of a ftring attached to its top. When the iron bar is in its place, its flat lower extremity is half an inch diftant from the bulb of a delicate mercurial thermometer, which is fixed by wax in a hole perforating the cylinder near its bottom. This thermometer is bent to a right angle, fo that its bulb and part of its ftem lie in the axis of the wooden cylinder. This fhape was preferred, becaufe the ftem could be little affected by the caloric tranfmitted by the fides of the veffel, till after the bulb was acted on by the caloric of the iron bar.

A variety of experiments was performed with this apparatus in the following manner: The temperature of the room being fteadily 67°, Fahren. therm.; during the trials, a kettle of water was kept boiling over the fire. Its temperature was between 211° and 212°, and in this the cylinder of iron was fuffered to remain, at each experiment, for fifteen minutes. The liquid to be examined, and all the apparatus (but the iron bar) were at each experiment afcertained to be at 67°. The liquid was poured into the wooden veffel, till it could rife $\frac{1}{10}$ of an inch on the fide of the iron cylinder when in its place. The wooden top was put on, and the iron was drawn out of the kettle of boiling water by means of the attached ftring, and inftantly let down through the hole of the cover. The time the thermometer took to rife through 3° (*viz.* from 67° to 70°) was accurately marked by means of a ftop-watch, and the refults of the experiments on feveral fluids, are exhibited in the following table.

Liquids.	Minutes.	Seconds.
Water - - - -	7	5
Cow-milk - - - -	8	25
Proof fpirit - - - -	8 nearly	
Alcohol. Lond. Pharmac. - - -	10	45
Tranfparent olive oil - - -	9	50
Mercury - - - -	9	15
Solution of fulphate of iron. Salt 1. Water 5.	8	
Saturated folution of fulphate of alumine	9	40
Saturated folution of fulphate of foda -	6	30
Aqua potaff. pura. London Pharm. -	8	15
Saturated folution of fulphate of foda, but the liquid not touching the iron cylinder, by $\frac{1}{10}$ of an inch, or nearly fo -	19	20

"If I am not deceived," says Dr. Traill, "we may conclude, from what I have above adduced, that liquids, as well as solids, are conductors of caloric; that the transmission of it through them follows a particular law depending on the properties of the particular liquid; but which is not in the exact ratio of any of their mechanical properties, though nearer that of their density, than any other."

A circumstance, deserving the attention of the speculative philosopher, respecting the conductors of electricity and of heat, has been observed; *viz.* that most of those bodies which are good conductors of the one, are likewise good conductors of the other. This law, however, is not without exceptions. Thus, metallic bodies are good conductors of both; but charcoal is a good conductor of electricity, though a very bad conductor of heat.

The last particular, which we shall briefly notice, with respect to the conductors of heat, is their use. This, on the least examination, will be found to be very extensive. Nature and art avail themselves of these peculiar properties of bodies, and without them both animal and vegetable life could not subsist. The atmospherical fluid which envelopes the earth, is a very bad conductor of heat, undoubtedly created for the purpose of not dissipating the heat of the earth and terrestrial bodies. The coverings of animals, such as furs and feathers, being extremely bad conductors, confine the heat on the animal body. The bark and ligneous part of plants, in consequence of their imperfect conducting powers, tend to prevent the freezing of vegetable juices. The industry of man has not omitted to use the worst conductors of heat for coverings, for the defence of his habitations, for the confinement of heat in certain furnaces, &c. In short, numerous and admirable effects are deduced by Providence, and several essential advantages are obtained by art, from a proper application of the various conducting powers of natural bodies.

Congelation

CONGELATION (from the Latin *congelo*), means the tranſition of a liquid into a ſolid ſtate, in conſequence of the abſtraction of heat; thus metals, butter, oils, water, &c. are ſaid to *congeal*, when, from a fluid ſtate, they paſs into that of a ſolid.

Congelation and freezing mean, in fact, the ſame effect; yet the term congelation is indiſcriminately applied to all the above-mentioned tranſitions; whereas the word freezing is more commonly uſed for denoting the congelation of water, of vinegar, of brandy, of mercury, and in ſhort of all thoſe ſubſtances which, in order to become ſolid, muſt be cooled below 32° of Fahrenheit's thermometer. We ſhall, however, in this work, divide the ſubject of congelation under the two above-mentioned denominations; ſtating, under the preſent article, whatever relates to natural congelation, and under the article Freezing, whatever relates to the artificial methods of freezing.

Another important proceſs, much connected with congelation, has been improperly ſeparated from it. And this is *cryſtallization*, or the arrangement of certain ſubſtances into regular figures, in their tranſitions from the fluid into the ſolid ſtate; but water and ſeveral other bodies likewiſe cryſtallize in congealing, which ſhews that the two proceſſes can hardly be ſeparated; and this is rendered ſtill more evident by a due conſideration of other phenomena that accompany both proceſſes. Allowing therefore that cryſtallization and congelation are eſſentially of the ſame claſs, a ſlight diſcrimination may be formed by applying the term cryſtallization to the formation of thoſe regular forms or cryſtals, which are of a compound nature, and which, when once formed, generally require a much greater degree of heat for their liquefaction, than that in which they were formed.

By far the greater number of liquids we are acquainted with, have been found capable of congelation in a proper temperature; and on the other hand moſt of thoſe ſolids which are ſuch in the uſual temperature of the atmoſphere may be rendered fluid by the application of certain appropriate degrees of heat; hence we are led by analogy to ſuppoſe, that every fluid might be congealed, if it were poſſible to cool it ſufficiently; or that fluidity is the effect or conſequence of heat. Every particular kind of ſubſtance requires a different degree of temperature for its congelation; hence it appears why certain ſubſtances remain always fluid, whilſt others remain always ſolid, in the ordinary temperature of the atmoſphere, and why certain other ſubſtances are ſometimes fluid, and at other times ſolid, according to the viciſſitudes of the weather, the difference of ſeaſons, and the variety of climates.

Heat, or ſenſible caloric, continually tends to paſs from thoſe bodies which have more of it than their proper ſhare, to thoſe contiguous bodies which have leſs of it than their proper ſhare; hence, when a body is placed amongſt other bodies of a lower temperature, its heat gradually paſſes to thoſe other bodies, until the whole acquires the ſame temperature; and this tranſition proceeds regularly, excepting, however, when the body is in the act of aſſuming the ſolid ſtate; for at that moment a ſudden extrication of heat is obſervable. Place a thermometer in a glaſs full of water,

and place the glafs in a freezing mixture of broken ice, and common falt, the thermometer will be found to defcend gradually as low as 30, or 28 degrees of Fahrenheit's thermometer, and fometimes even much lower, whilft the water remains fluid; but, at laft, the water begins to freeze, and at that very moment the thermometer rifes fuddenly to 32°, and it remains at that point until the whole of the water is congealed. If then the application of the freezing mixture be continued, the thermometer will fink gradually feveral degrees below 32°, according to the activity of the freezing mixture. We may, Dr. Black obferves, eafily fatisfy ourfelves, that the water, while congealing, is continually imparting heat to the furrounding air; for, if we fufpend a delicate thermometer immediately above the water, we fhall find the inftrument affected by an afcending ftream of air, lefs cold than the air around.

Not only pure water, but all aqueous fluids, may be cooled down 7, or 8, or 10 degrees without freezing; but if in that ftate they be affected with a tremulous motion, or if they be touched with a flender piece of ice, they will inftantly fhoot into beautiful fpiculæ, the thermometer in it rifing at the fame time. This ftriking phenomenon of the fudden rifing of the thermometer at the moment of congelation, which has alfo been remarked in wax, fpermaceti, and other fubftances, has not yet been fully or fatisfactorily explained. It is true that ice has not fo great a capacity for containing heat as water has; (fee the capacities of bodies under the article Caloric and Heat); but why fhould water fo reluctantly part with that fuperfluous quantity of heat as to fuffer itfelf fometimes to be cooled feveral degrees below 32, before it will affume the folid form?

Since water, when it has once begun to congeal, remains at the apparent temperature of 32° until the whole of it is congealed; and fince water cannot remain congealed in a temperature higher than 32°; therefore the congealed point of water has been fixed at 32°. of Fah.

The congealing points of feveral other fubftances have alfo been afcertained with confiderable accuracy. In fome, however, it is not the congealing, but the melting, point that has been afcertained. Thefe two points, if they be not quite the fame, may naturally be fuppofed not to differ more than about a degree or two; hence from the latter the former may be eafily deduced. In the following table, however, we fhall fet down the one or the other of thofe points, according as either of them has been more accurately determined.

Table of the congealing, or melting points of different fubftances, expreffed in degrees of Fahrenheit's fcale; the high degrees of which have been eftimated by the equivalent degrees of Wedgwood's thermometer.

Platina melts	23177°. F.
Manganefe melts	28877.
Iron melts	21637.
Nickel melts	20577.
Pig iron begins to melt / Cobalt melts	17977.
Fine gold melts	5237.
Settling heat of flint glafs	4847.
Fine filver melts, according to Mr. Wedgwood	4717.
Fine filver melts, according to Sir James Hall	393[illegible]
Swedifh copper melts	4587.
Brafs melts	3807.
Zinc melts	700.
Lead melts, according to Newton	540.
Lead melts, according to Seconat	585.
Lead melts, according to Irvin	594.
Lead melts, according to Parker	612.
Lead fixes, according to Crichton of Glafgow	612°. F.
Bifmuth melts	460.
Bifmuth melts, according to Irvin	470.
A mixture of one part of tin and four of lead, melts	476.
Tin melts	408.
Tin melts, according to Irvin	413.
Tin melts, according to Crichton of Glafgow, it congeals at	442.

The laft mentioned gentleman fays, "in melted tin the thermometer funk gradually till it arrived at 442°; then it inftantly funk to 439°; and as inftantly rofe to 442°. At this temperature the mercury remained perfectly ftationary for five minutes, at which time the metal became folid to the centre of the crucible."

A mixture of three parts of tin and two of lead melts / A mixture of two parts of tin, and one of bifmuth melts	334.
A mixture of tin and bifmuth, in equal parts, melts	283.
Sulphur melts	234.
A mixture of five parts of bifmuth, three of tin, and two of lead, melts	212.
A mixture of three parts of tin, five of lead, and eight of bifmuth, melts	219.
Serum of blood begins to coagulate at	156.
Albumen, or the white of an egg, coagulates at	156.
Bees wax melts	142.
Tallow melts	127.
Spermaceti melts	112.
Ice, or congealed water, begins to melt	32.

The increafe of the bulk of water previous to, as alfo following, its point of congelation is a remarkable property, which has been more or lefs obferved with all aqueous fluids, *viz.* they are contracted by cold, until a certain limit, which generally is about 7 or 8 degrees higher than their congealing point; they then expand again as they are cooled farther, and if they are not agitated, they will remain liquid at a temperature lower than their congealing point. The greateft denfity of water, Count Rumford fays, is fomewhat lower than 40°. Profeffor Hope of Edinburgh places it between 39°.5 and 40°. Mr. Dalton fays, that the greateft denfity of water is at the temperature of 42°.5. And that the expanfion of water is the fame at the diftance of the fame number of degrees above and below 42°.5. Thus the expanfion is the fame at 32° and 53°; the fame at 10° and 75°, &c. The increafe of bulk in freezing water is not owing to the formation of air bubbles, for water, which has been deprived of air, will alfo expand in freezing. The bulk of ice, at a mean, is to that of the water which it produces, as 9 to 8. This enlargement of bulk is attributed to a cryftallization; the particles of water in freezing tend to arrange themfelves fo as to form angles of about 60 and 120 degrees; and this tendency is exerted with a prodigious force. Mr. Leflie fays, "water neceffarily difcharges its air previous to the act of congelation; a circumftance which fometimes retards that fpecies of cryftallization. Hence it is, that water freezes fooner which has been boiled. When expofed to cold, crude water will prefent a cake of ice crowded with large bubbles entangled in the mafs; but boiled water will contain a folid lump, almoft pellucid, with only fome minute fpecks or ftriæ fhooting from the centre." Dr. Black fays, that boiled water begins to freeze as foon as the air has cooled it to 32°. Iron likewife occupies lefs room when fluid than when folid. And the fame thing has been afferted of two or three other metallic fubftances:

Vinegar congeals at about - - - 28°. F.
Human blood congeals at - - - - 25.
Strong wines congeal at about - - - 20.
A mixture of one part of alcohol and three of water congeals at - - - - - - 7.
A mixture of alcohol and water, in equal parts, congeals at - - - - - - - *minus* 7.
A mixture of two parts of alcohol and one of water, congeals at - - - - - *minus* 11.
Mercury congeals at - - - - *minus* 39.

Mercury exposed to cold, and at about the point of congelation, contracts its bulk irregularly. This substance may be cooled some degrees below its freezing point, before it assumes the solid form; but as soon as it begins to harden, the thermometer rises to its freezing point, which, from a variety of experiments made by Mr. Hutchins at Hudson's Bay, appeared upon his thermometer to be —40°. "But (Mr. Cavendish observes in the Phil. Transf. vol. lxxiii. p. 321.) as it appeared from the examination of his thermometer, after it came home, that —40° thereon answers to —38⅔ on a thermometer adjusted in the manner recommended by the committee of the Royal Society; it follows, that all the experiments agree in shewing that the true point at which quicksilver freezes, is —38⅔, or in whole numbers 39° below nothing."

In becoming solid, mercury sometimes shoots into crystals or longitudinal filaments like pins. The first observations concerning the natural congelation of mercury were made by Mr. Gmelin about the year 1735, at Yenefeick in lat. 58½° north, at Yakutsk in lat. 62° north, at Rivengo, lat. 57½° north, and elsewhere. (See the Petersburg Commentaries for the years 1756 and 1765). Professor J. A. Braun, of Petersburg, in the year 1759, first accomplished the congelation of mercury by art, *viz.* by means of snow and aqua fortis. But with respect to the artificial methods of congealing mercury, and their history, see the article FREEZING.

Nitric acid is said to congeal at - - *minus* 66.

With respect to the congelation of the sulphuric, or vitriolic acid, the greatest number of experiments seems to have been made by Mr. Keir, and from those experiments he infers: "1. That the vitriolic acid has a point of easiest freezing, and that this is when its specific gravity is to that of water as 1780 to 1000. 2. That the greater or less disposition to congelation does not depend on any other circumstance than the strength of the acid. 3. That the freezing and thawing degree of the most congealable acid is about 45° of Fahrenheit's scale. It is, however, to be observed, that this degree is inferred from the temperature indicated by the thermometers immersed in the freezing and thawing acids; but the congelation of the fluid acid could never be accomplished without exposing it to a greater degree of cold, either by exposing it to the air in frosty weather, or to the cold of melting snow. 4. Like water, this acid possesses the property of retaining its fluidity when cooled several degrees below the freezing point; and of rising suddenly to it when its congelation is promoted by agitation, or by contact even with a warmer thermometer. 5. That, like water and other congealable fluids, the vitriolic acid generates cold by its liquefaction, and heat during its congelation, though the quantity of this heat and cold remains to be determined by future experiments 6. That the acid, by congelation, when the circumstances for distinct crystallization are favourable, assumes a regular crystalline form, a considerable solidity and hardness, and a density much greater than it possessed in its fluid state."

The heat of the earth, at least on the surface of it, is derived entirely from the sun; for the heat arising from combustion, as about volcanos, or from decomposition of bodies, is trifling and partial. The direct rays of the sun on the same spot of the surface of the earth heat it more or less, according to the time of the year, clearness of the atmosphere, state of the winds, colour and quality of the spot. In Great Britain, during the hottest time of the summer season, the direct rays of the sun seldom raise the mercury in the thermometer so high as 110°. But in other climates, especially within the tropics, the mercury is raised considerably higher by the like exposure. Yet we must not believe the idle stories of the sun's heat melting lead, or setting fire to gun-powder, without the assistance of lenses, speculums, or other artifice.

It is not on account of the sun's being nearer or farther from the earth, that we receive much more heat in the summer than in the winter time; since the difference of those distances is too small to be sensibly felt; but we receive more heat in the summer than in the winter season. 1. Because the sun comes nearer to our zenith in the summer than in the winter time, in which situation its rays pass through a shorter portion of the atmosphere, and of course are less intercepted by it. 2. Because, when the sun is nearer to the zenith, a greater quantity of its rays falls upon a given horizontal part of the surface of the earth, than when that luminary stands lower, and its rays fall more obliquely upon the same spot. 3. Lastly, because the sun remains longer above the horizon during a summer day than a winter one.

The hottest part of the day is not at noon, nor that of the year when the sun passes nearest the zenith of a given country; but the hottest part of the day, when no accidental circumstance intervenes, is some time in the afternoon, and nearer to noon in the winter than in summer. In this country and in summer, the hottest part of the day generally is either precisely at, or a little before, two o'clock. The hottest time of the year in this country generally takes place in July, *viz.* after the solstice. The reason of this is, that though the rays of the sun give more heat when the sun stands higher, and of course at two o'clock they must give less than at noon; yet the earth, and the air contiguous to it, are hotter at two o'clock, because, besides the heat which they are actually receiving from the sun, they retain a considerable portion of the heat acquired before that time; so that as long as they acquire at any particular time, a greater quantity of heat than they lose of that which they had previously acquired, their temperature must continue to increase. The same thing must be understood with respect to the communication of cold, which, for similar reasons, is greatest some time after midnight, and some time after the shortest days of the year. The earth acquires heat in the day time, and loses it during the night. In the summer season the loss of heat during the night is less than the acquisition of it during the day; therefore that excess of heat is gradually communicated from the surface to the more internal parts of the earth. But when the above-mentioned summer heat has penetrated a certain way, the winter cold begins to counteract it; and when that cold has penetrated a certain way, the next summer heat begins again to counteract it, and so on; hence, below a certain depth there is no alteration of temperature at any time of the year; unless some local combustion or other source of heat should interfere, which, however, seldom occurs. This fixed degree of temperature at a certain depth below the surface of the earth, varies in different countries, and nearly coincides with the mean temperature of the particular country. Thus in London the mean temperature is 50°; and if a bucket of water be drawn from a pretty deep well, and a thermometer

be instantly placed in it, the temperature of that water, (which is the same as that of the ground surrounding the bottom of the well) will also be found to be 50°. In process of time the mean temperature of a country is liable to some alteration arising from cultivation, clearing of grounds, draining of marshy grounds, &c. See CLIMATE.

With respect to the temperature at different altitudes, it has been found that a thermometer placed close to the ground is sometimes affected by heat or cold, sooner, or in a greater degree, than a thermometer placed 20, or 30, or 60 feet, higher up; and that at other times the latter is affected sooner, or in a greater degree, than the former. In the night time, especially when the air is still, and the sky quite free from clouds, a thermometer close to the ground generally indicates a greater degree of cold than in a higher situation. The true cause of this phenomenon is not fully understood; though it is attributed to evaporation, or according to Mr. Six, to the coolness which the dews or vapours may acquire in their descent.

At great heights above the surface of the earth, either in the free air, or on the summit of high mountains, the cold is much greater, and it increases more suddenly; 1st, because they are much more exposed, and 2dly, because they are more remote from the body of the earth, which, as has been observed above, tends to equalize the temperature, by retaining in the winter time a considerable degree of the heat acquired in the course of the summer. The winds to which mountains are exposed, especially those which, after having blown over the plains below, rise along their sides, have a peculiar refrigerating power, arising from the expansion of the ascending air, which becomes capable of absorbing more heat in proportion as it is more rarefied. See Dr. Darwin's Paper, Phil. Transf. for 1788.

Thus we have briefly stated the natural sources, and the principal causes which check or promote the heat and the cold, that are usually experienced in the world, at different times of the day, of the year, and in different countries; whence alone one may pretty well conceive where and when natural congelation may be expected to take place. Yet it is necessary to subjoin some farther observations, that have been made with respect to natural congelation at different times and different places.

The greater obliquity with which the sun's rays fall upon the northern and southern parts of the earth, than they do upon such parts as are near the equator, undoubtedly produces the variety of the mean temperatures that are observed in different latitudes; the higher latitudes being generally colder than the lower, and *vice versâ*. But this gradation is partly counteracted by a variety of local circumstances; and such are the vicinity of large tracts of land or great extent of sea, the face of the country being flat or hilly, the disposition of the hills and mountains, the prevalence of rain and of certain winds, the state of cultivation, &c. The influence of winds in certain latitudes is so very great that a frost or thaw is brought on within a remarkably short time by a change of the wind. The action of winds on the temperature of a country principally depends upon three circumstances, *viz.* on their bringing a quick succession of new air in contact with the bodies that are exposed to it, on their having passed over the surface of hotter or colder tracts of water or land, and upon their increasing the evaporation. Saussure found that when the wind moves at the rate of forty feet per second, it triples that quantity of evaporation that would take place in calm air; hence it follows that frequently unusual heats or colds come on at unexpected times, and that the higher strata of the atmosphere are often warmer than the lower; for the heat of the atmosphere is derived not from the immediate action of the sun's rays which pass through it, but from the warmer and more solid bodies with which it has been, or is, in actual contact. In consequence of these various circumstances, it has been observed that the north Pacific Ocean, above latitude 40°, is much colder than the north Atlantic, between the same parallels of latitude. The interior parts of Siberia, east of longitude 100°, are much colder than the parts equally distant from the meridian on the western side. The coast and interior parts of the western regions of America are much colder above the latitude of 40°, than the corresponding tracts of the continent of Europe. Large seas, which are agitated by winds and currents, are thereby so little affected by cold winters or hot summers, as to preserve a temperature nearly uniform in every season, like the internal parts of the earth.

With respect to the mean temperature of places at different altitudes above the level of the sea, but in the same country, or nearly about the same spot with respect to latitude, the heat diminishes nearly one degree of Fahren. for every 200 feet of elevation, according to Dr. Black. Other writers find reasons to assert, that the diminution of one degree takes place at every 299 feet of elevation.

From the statement of all the above particulars the reader may form some idea of the time and place when natural congelation may be expected, and he will at the same time be able to perceive that close to the surface of the earth, no great regularity can be expected. On the continent of Europe congelation formerly took place at a lower latitude than it does at present, when natural congelation is seldom observed lower than the latitude of 40°. In America congelation has been observed at a much lower degree; and it is remarkable that great degrees of heat, as well as great degrees of cold, are alternately experienced on the same spots of that continent. In the more northern parts of the world the degrees of cold are very extraordinary. At Torneao, Reaumur's spirit thermometer fell to minus 34°. In Siberia the spirit thermometer has been known to descend as low as minus 121°. Even at the Glasgow observatory in the year 1780, the mercury of the thermometer exposed to the ambient air was found to stand at minus 14°.

The altitude on the sides of mountains, at which constant congelation takes place, seems to be less fluctuating, though not accurately ascertained. This altitude varies with the latitude; but even in the torrid zone perpetual congelation has been observed (according to Bouguer and others) at the altitude of about 15600 feet. This altitude, at which the congelation is constant, or where water ceases to be a fluid, and beyond which visible vapour does not seem to ascend, is called the *upper line of congelation*. The *lower line of congelation* is where it freezes at night only. The upper line of congelation, within the tropics, has been observed at the altitude of 15600. Near the tropics, on the sides of the temperate zones, it lies at the height of about 13428 feet. On the island of Teneriffe, in lat. 28° N., it lies at the altitude of about 10000 feet. In Auvergne, lat. 45° N., the line of congelation is at the altitude of 6740 feet. In latitude between 51° and 54° N. it seems to be at the altitude of about 5800. In latitude 80° north, lord Mulgrave found the line of congelation at the altitude of about 1200 feet above the level of the sea; whence, if the progression continues uniformly, as general Roy observes, we may conclude that the surface of the earth, at the pole itself, is for ever covered with congelation. Mr. Kirwan, however, places the upper line of congelation considerably higher. See his paper on the variations of the atmosphere, in the 8th vol. of the Transf. of the

Royal Irish Academy. He reckons the altitude of the line of congelation from 0° to 10° of north latitude, at about 27700 feet; from 10° to 15° at about 26400 feet; from 15° to 20°, at about 25200 feet; from 20° to 25°, at about 24000 feet; from 25° to 30°, at about 22000 feet; from 30° to 35°, at about 20000 feet; from 35° to 40°, at about 17000 feet; from 40° to 45°, at about 15000 feet; from 45° to 50, at about 12500 feet; and for every one of the other degrees of latitude, at the altitudes which are annexed o them in the following table. These results, however, he deduced by computation from a few ascertained particulars.

Degrees of N. lat.	Altitude of the line of congelation.	Degrees of N. lat.	Altitude of the line of congelation.
51°	10124	71°	4354
52	8965	72	4295
53	7806	73	4236
54	6647	74	4177
55	5617	75	4119
56	5533	76	4067
57	5439	77	4015
58	5345	78	3963
59	5151	79	3911
60	5148	80	3861
61	5068	81	3815
62	4989	82	3769
63	4910	83	3723
64	4831	84	3677
65	4752	85	3631
66	4684	86	3592
67	4616	87	3553
68	4548	88	3514
69	4480	89	3475
70	4413	90	3432

Cooling

COOLING is the progressive decrease of temperature from a higher to a lower degree. From the highest degree of heat, which human industry has been able to obtain by means of combustion, or by concentrating the solar rays, to the lowest degree of it, which both natural and artificial methods have produced, the scale is very considerable; and different parts of it have obtained diverse denominations, which are derived from the most striking phenomena that take place at particular points of the scale; thus we hear of porcelain heat, white heat, red heat, boiling heat, temperate, freezing, &c. and all these transitions from the first to the last, fall under the denomination of *cooling*; whereas the contrary transition from the lowest to the highest, is called *heating*. In order to preserve perspicuity, and to assign to each of the received denominations, the particulars which belong more immediately to it, we have divided the subject into three articles, under the words *congelation*, *cooling*, and *freezing*. Under the first we have stated the phenomena of natural congelation; the last contains whatever relates to artificial freezing, *viz.* to the production of cold below 32° of Fahrenheit's scale; and under the present, we shall principally state all the methods and the effects of cooling from the actual temperature of the atmosphere to a lower degree; but not below that of melting ice, *viz.* 32°, which is commonly called the freezing point.

The temperature of the atmosphere in the hottest climates, has hardly ever been known to exceed 130°, and it is but seldom that it reaches that most oppressive degree of heat. In the human species, nature has made ample provision, and has furnished them with industry sufficient for counteracting the effects of a very high or a very low temperature; but without any artificial assistance, few are the degrees of heat in which human beings can live with perfect comfort. Making some allowance for the natives of different climates, the whole range temperature may be said to reach from the 60th to the 70th degree of Fahrenheit's scale. Below 60° most persons have no objection to a gentle fire in their apartments; and above 70° they generally complain of heat. Yet when the natural temperature of the atmosphere is above 50°, cooled liquors are generally preferred for drink; but when the temperature is above 70°; then not only cooled liquors, but cool apartments also, are articles of great luxury; and (it may in great measure be said) of necessity. The languor which is commonly induced by heat, is in great measure relieved by artificial cooling. Patients affected with fevers of the intermittent and putrid kinds, which are so very common and destructive in hot climates, receive great benefit from the use of cooled liquors, and such are plentifully administered to them, whenever they can be obtained. The preservation, likewise, of meats, fruit, butter, &c. in warm climates, or in the hot season, is considerably assisted by cooling; and it may be extended to a very remarkable long period by actual freezing.

In order to answer all these purposes, mankind has, from time immemorial, endeavoured to discover and to apply me-

thods of cooling, or of refrigeration. These methods, as far as they are at present known, may be comprised under the following heads; *viz.* 1st, the application of something naturally colder than the actual temperature of the atmosphere; 2dly, ventilation; 3dly, evaporation; and 4thly, the solution of certain saline substances. Sometimes two or three of these means are applied at the same time, to the article which is required to be cooled. In every country of Europe, and especially in the southern part of it, ice is collected during the winter, in proper places, and is used for cooling liquors, &c. in the summer season, or throughout the whole year. And this undoubtedly is the most easy, the most extensive, and the most effectual method of cooling. A little ice taken out of the ice-house, and placed round a bottle of water or wine, in any convenient vessel, soon cools it to the desired degree; and if the effect is to be increased, so as to freeze creams, fruit, &c. by breaking the ice into small pieces, and mixing common salt with it, the desired end will be obtained. The ice-house itself is of very essential use for preserving meat, fish, butter, fruit, &c. which things need only be laid in it, until they are wanted.

When ice cannot be easily procured, well water forms a useful substitute to a certain degree. When the depth of the well is 40 or 50 feet, or upwards, the constant temperature of its water is very nearly equal to the mean temperature of the country, which, of course, is lower than the usual temperature of the summer season in that country; hence, if a pail of water be drawn, and a bottle of wine, or other liquor, be immediately placed in it; a considerable refrigeration may be obtained, and it may be maintained by drawing fresh water at intervals from the well, &c. Thus in London the mean temperature is about 50°, and so is the temperature of pretty deep wells throughout the year. Now in the summer season, the temperature frequently rises above 65°, or 70°; therefore, at those times, by applying fresh drawn well-water, the liquors we drink may be cooled about 15 or 20 degrees, which will render them incomparably more pleasant. When articles of food are required to be kept some time longer than the heat of the weather would allow, they may be placed in a basket at the end of a rope, and may be let down into the well, until they come within a foot or two of the water. For the like purposes, pretty deep pits, caves, or grottos may be used; since their temperature is nearly equal to the mean temperature of the country, and suffers little or no variation between winter and summer.

Ventilation is nothing more than a constant change of air; but if the air which has just passed by a body, and that which succeeds it are all of the same temperature, no cooling will be produced by the ventilation; but the refrigeration will take place, when the body is hotter than the air which passes by it, or when an increase of evaporation ensues. Expose a thermometer to the open air, but shelter it from the wind, and when the thermometer is become stationary, let the wind fall upon it; and it will be found that the quicksilver is not lowered in it. But when a human being, or other animal is exposed to ventilation, the quick transition of air cools it; first, because it continually removes the air which has been heated by the contact of the animal body, the breath, &c.; and secondly, because the evaporation from the body is increased by the ventilation. So that, upon the whole, the use of ventilation, such as is effected by means of fans, bellows, a particular disposition of apartments, and other machines, is to remove heated or vitiated air from the vicinity of human beings, from close habitations, prisons, ships, &c. The ingenious Dr. Hales fixed a machine of this sort in the old Newgate prison, which, being put in action by means of sails, like a wind-mill, constantly ventilated the inside of that prison; and this machine remained in use until the rebuilding of that prison upon a better plan rendered it superfluous. See VENTILATOR.

Hitherto we have supposed, that the air is colder than the human beings who are exposed to it; but should the contrary be the case, then ventilation will produce a different effect; *viz.* it will heat, instead of cooling, as may be easily conceived by considering what has been said above. And such is the case with the hot winds, which sometimes blow in Arabia, Africa, India, and other places.

One of the most useful and efficacious modes of cooling, especially in those countries where it may be mostly wanted, is performed by means of evaporation. The principle upon which the cooling power of evaporation depends, is, that whenever a body is expanded, *viz.* its volume is increased, its capacity for containing heat is increased at the same time; hence the expanding body absorbs the heat of the surrounding bodies, which, of course, are cooled by it.—A short experimental illustration of this theory will easily explain the effect we are treating of. Take three common mercurial thermometers: keep one in its natural state; place the second in a bottle of water, and close its aperture; wrap some cotton moistened with water round the bulb of the third; then expose all the three thermometers thus prepared to the ambient air, especially when the wind blows in the summer season; and after a few minutes observe their progress. It will be found that the naked thermometer, and that which stands in the bottle, indicate the same degree of temperature; but the third thermometer, which is wrapped in moistened cotton, will be found to indicate a temperature lower by a few degrees, than the former. The effect in this experiment is produced by the evaporation of the water from the cotton, and not from the water as water; for if that were the case, the thermometer in the bottle of water would likewise be cooled like the one involved in moistened cotton. Evaporation is the conversion of water into steam, or vapour; and the bulk of steam has been found to be many hundred times larger than the bulk of the water from which it originated. Now in that expanded state, steam is capable of holding a vast deal more of the element of heat, than in its form of water, and that without manifesting any higher degree of temperature. Or, in other words, if a thermometer be placed in a bottle full of vapour of water, and another thermometer be placed in the water from which that vapour was just produced, their temperatures will be found to be nearly the same; yet the vapour contains a vast deal more of the element of heat than an equal weight of water, which quantity of heat is essentially necessary for maintaining its elastic or vapourous existence; and this is proved by observing, that vapour cannot be converted into water without depositing its heat upon (and of course elevating the temperature of) the surrounding bodies; and on the other hand, that water cannot be converted into vapour, without absorbing heat from (and consequently cooling) the surrounding bodies. Mr. Watt of Birmingham says, that he has observed as exact a coincidence between the heat rendered latent in the vapour, and that which emerges from it, as can be desired; and that the heat obtainable from steam, capable of sustaining the ordinary pressure of the atmosphere, is not less than 900°; and that it does not exceed 950° of Fahrenheit's scale.

The cooling action of evaporation is counteracted by the influx of heat from the surrounding bodies, since heat always tends to equalize the temperature of contiguous bodies. Thus in the above described experiment, the heat of the surrounding air tends to elevate the temperature of the

thermometer, at the same time that the evaporation from the cotton tends to lower it. And according as the one or the other of these opposite actions predominates, so the cooling effect is more or less conspicuous. From these observations it naturally follows, that the cooling, occasioned by evaporation, is greater when the evaporation is quicker, and contrarywise; also, that when different fluids are used for the evaporation, in similar circumstances, that fluid which evaporates quickest, produces the greatest refrigeration. Mr. Cavallo says, "in order to try the degree of refrigeration produced by the evaporation of different fluids, I held up a naked thermometer, (*viz.* a thermometer, the bulb of which was not in contact with the metal of the scale) and poured upon its bulb a stream of some particular fluid, which issued out of the capillary aperture of a tube; taking care to throw just fluid enough to supply the waste by evaporation. By this means, when the temperature of the air was 64°, I found that the evaporation of water cooled the thermometer 8°; *viz.* brought it down to 56°; the evaporation of spirit of wine cooled it 16°; *viz.* brought it down to 48°; and the evaporation of ether cooled it 54°; *viz.* brought it down to 10°. But, by the use of the best purified sulphuric ether, when the temperature of the air was about 56°, I brought the thermometer down to 3°. The cooling produced by the evaporation of other fluids needs not be mentioned; their effect being generally intermediate between the effect of water, and that of spirit of wine." (Phil. Transf. vol. lxxi.) Whatever promotes the evaporation, such as a dry air, and especially a dry wind, tends to increase the refrigeration; and when all the favourable circumstances concur, the effect is prodigious; so that in a dry, warm, and brisk wind, by means of the evaporation of the best sulphuric ether, the temperature of any kind of bodies may be lowered many degrees below the freezing point; and animals might be easily frozen to death.

Though several of the above-mentioned particulars, and especially the causes upon which they depend, have been but lately investigated and ascertained; yet the cooling effect of evaporation has been known and used by mankind from time immemorial. Athenæus says, as being related by Protagorides of Cyzicum, that in the time of king Antiochus, it was usual to cool water by evaporation, and to drink it as a luxury. A very easy and familiar experiment to shew the effect of evaporation, may be performed in the following manner. Moisten a small space on the upper part of each hand; cover one of those places with an inverted wine glass, and let a person blow with a pair of bellows upon the other hand. The latter will be sensibly cooled, but not the former. Change the glass and the blowing, from one hand to the other, and the effects will be reversed. Seamen, especially in the night time, frequently employ this natural effect for discovering which way the wind blows. They moisten a finger of their hands by putting it in their mouth; then expose it to the ambient air by elevating it above their head; and justly conclude that the wind blows from that quarter which is opposed to the most cooled side of the finger.

In warm climates, where the dryness of the air generally is very great, the refrigeration arising from evaporation is very considerable, and is of course frequently employed for counteracting the natural heat. The caravans which traverse the parched deserts of Arabia, are obliged to carry their supply of water in earthen jars upon camels; but in order to keep it pleasantly cool, the jars are involved in cloths, which they take care to keep continually moistened with water. It is a pretty common practice in the southern parts of Europe, as well as in the East and West Indies, in America, &c. to wrap up a bottle of wine, or water, or other liquor, in a wet cloth, and thus to suspend it in a shady place, either under a tree or in a passage, so as to expose it to the briskest current of air that can be obtained; for by this means the liquor will be cooled several degrees; care, however, must be had to sprinkle more water upon the cloth, which surrounds the bottle, in proportion as the former evaporates. Mr. Walker, of Oxford, describes a peculiar method of producing a very considerable degree of cold by means of evaporation. "Having," he says, "in the course of the preceding winter, frequently succeeded in producing ice, by the cold produced from evaporation with water, when the temperature of the air was 38°; it occurred to me, that it might be possible to freeze water in the middle of summer, by a process which depended on this principle, by the use of water only. Accordingly, I procured a tall cylindrical vessel, holding about two gallons, in which is fixed a small spiral tube, as in the worm-tub of a common still; the lower end of this tube comes out through the vessel near the bottom, sufficient to connect the nosle of a pair of bellows to it, by the intervention of a bladder, secured air-tight; this spiral tube ends at the top of the cylindrical vessel, where it is somewhat enlarged, like the mouth of a funnel. This vessel, being covered with flannel, was filled with water and hung out in a brisk dry wind, the temperature of the air being 50°; after some time, by repeatedly wetting the flannel on the outside of the vessel, I found the water within was cooled to 40°; air being then forced through the tube (by means of the bellows), surrounded by the cooled water, came out at the upper extremity of the tube at nearly the same temperature.

"A thermometer having its bulb covered with lint, and wetted repeatedly with the cold water in the vessel, placed so as to receive the draught of cold air from the tube, soon sunk to 34°; hence by a series of two or three of these vessels, water might, upon this principle, be frozen at midsummer, recollecting that this experiment may always commence at 50°, the usual temperature of springs; and hence it might be possible upon the same principle, to cause nature upon a small scale, even without the immediate interposition of art, to depart from her usual course, and to assume the hoary garb of winter at midsummer.

"For this purpose a current from the external air might be admitted into the tube, by means of a funnel, communicating with, and receiving, a constant draught of air.

"In an attempt of this kind, it would be necessary (besides some other variation in the vessels, which circumstances might point out,) that the cylindrical vessels be porous, or pierced with small holes; so that the water may be constantly and gently oozing out."

In Spain, in Italy, in Egypt, and probably in other places, certain vessels are made of a porous earth, which, when full of water, will just permit some of that fluid to ooze out on their external surface, whence it evaporates, and thus cools the remainder of the liquor within the vessel. The Spanish vessels for this purpose consist of a reddish brown earth. They are pretty broad, but not very capacious. In Italy they have been made of a pale yellowish material, but much larger. In Egypt they are made somewhat in the shape of a Florence flask, and not much bigger; but their aperture spreads out in the form of a cone, or rather of an ale glass, which is done for the conveniency of drinking out of it. Their substance is of the colour of ashes, and it is said to be a scum left on the banks of rivers. But vessels of any degree of porosity may be made by mixing sand and clay in various proportions.

The use of these vessels in Spain, in Italy, and especially in Egypt, is attended with a notable degree of refrigeration, on account of the great dryness of the air in those climates, which enables it to absorb a great deal of moisture in a short time; but the same vessels having been brought over, and having been tried, in this country, have been found to cool the contained liquor in a very trifling degree; evidently owing to the state of the air in this country, which is much less hot, and much less dry than in the above-mentioned places; therefore much less apt to promote evaporation. One of the Egyptian vessels was tried in London at a time when the temperature of the atmosphere was at a mean, and after about half an hour, when almost three quarters of the water had passed through it, and had dropped down, the remaining quantity of water was found barely 3° colder than the surrounding air.

It is but lately that liquor coolers have been manufactured in this country, and they are at present to be found in most of the earthenware shops in and about London. These are cylindrical vessels, about six inches in diameter, and about a foot high. It is directed to keep one of these vessels entirely immerged in water during one hour. The vessel, being then removed, in that moist state, without putting any water in it, a bottle of wine, &c. must be placed in it, and this is said to be cooled by the evaporation of that quantity of water, which the substance of the vessel had imbibed whilst it remained under water. Upon trial, however, it appears that the actual refrigeration which is obtained by means of one of these vessels, seldom amounts to two or three degrees; and that, of course, a bottle of wine may be cooled much more effectually by placing it into a pail of water fresh drawn from a pretty deep well or pump; which may be renewed at intervals. Indeed, considering the form of these coolers, also that the sides of it are at a considerable distance from the surface of the bottle, and the ambient air has a free access to both, it is hardly to be expected that any sensible advantage should be obtained from them.

In India the action of evaporation is used not only for cooling liquors, but likewise for cooling apartments, and the effect, by the testimony of those persons who have experienced it, is said to be very remarkable. The method, (which, however, is practicable only when a dry wind blows,) is as follows. That door of the apartment which is opposed to the wind, and through which the wind enters, is stopped up with a peculiar sort of screen or curtain, which fits it exactly. This screen consists of two surfaces or gratings of bamboo, situated parallel to each other, and about three or four inches apart; then the space between these external surfaces is filled up in a loose manner with the roots of a sweet-scented grass. In short the construction of this screen is calculated to admit the air not in a body, but divided through a vast number of passages. Two men are placed on the outside, each having a goat's skin filled with water, which they keep continually sprinkling upon the screen. A constant and copious evaporation is of course kept up, which presently cools the adjoining room to a very remarkable degree. By this means the temperature of the room has sometimes been lowered upwards of 15°.

Amongst those cooling processes which depend upon the expansion of bodies, that which arises from the expansion of air must not be forgotten; but as this is by no means very practicable, we shall barely mention it in this place. The condensation and expansion of air produce the effects which have been mentioned above; viz. the former is attended with an extrication of heat, and the latter with an absorption of it; hence the contiguous bodies are heated by the former, and are cooled by the latter. When air is suddenly condensed, (see CONDENSER, and CONDENSATION,) the heat which is extricated from it, has been found capable of setting fire to light combustible bodies; and when the air is rarefied either by means of an air-pump, or by liberating it from a vessel, in which it has been condensed; the cold it produces has sometimes been found to lower the thermometer several degrees below the freezing point.

The last method of cooling which remains to be described, is obtained by the solution of salts. That certain saline substances, whilst dissolving in water, or in acids, would generate a considerable degree of refrigeration, and especially that the solution of salt ammoniac would lower the thermometer down to the freezing point, has been long known; but, within these 15 or 20 years, the subject has received wonderful improvements, in consequence of the experiments instituted by various ingenious persons; and especially from the assiduous investigations, and successful experiments of Mr. Walker of Oxford, who has examined the cooling powers of a vast number of saline substances both single and mixed; and has been able to freeze quicksilver at Oxford in the middle of summer, merely by the solution of salts. His interesting experiments, and his various freezing mixtures, will be found described under the article FREEZING.

A vast number of salts and saline mixtures may be used for cooling liquors; but the most advantageous are those which, after solution, may be recovered by means of evaporation, so as to render them useful for a second refrigeration, a third, and so forth. Yet the price of most of those salts in Europe, the trouble of recovering them from the solution, and pounding them in order to render them fit for another cooling operation, have not rendered this method common in this part of the world; especially where other easier methods are practicable. So that in fact the cooling power of saline solutions is mostly used for particular experiments by the European philosophers, especially when a very powerful freezing mixture is required. In India, where nitre is very cheap, and the heat of the climate prompts the inhabitants eagerly to adopt every possible method of cooling, the practice of cooling liquors, by means of the solution of nitre in water, is very common. For this purpose, the wine, the water, or any other liquor, is put into a metallic bottle, generally a pewter one, having a pretty long neck. A tub is partly filled with water, and a quantity of nitre is thrown in it; then the operator holds the bottle by th upper end of its long neck, and gently moves it about the saline solution, and thus cools the liquor in it to a very considerable degree. As salts will produce cold only during their solution, therefore when the first quantity of nitre has been thoroughly dissolved in the above process, more nitre must be added; and when the water is completely saturated, so as not to be capable of dissolving more salt, then the bottle must be removed to another tub with a fresh saline mixture. The nitre might afterwards be easily recovered merely by exposing the solution, in shallow pans, to the hot rays of the sun in that country; this economical plan, however, does not as yet seem to have been adopted.

The salts which might be used for the purpose of cooling liquors in this country, or in long voyages, are nitre and salt ammoniac; the other saline substances being either more expensive or not easily recoverable after solution. Of the effects of nitre alone in water enough may be derived from the above described process. Salt ammoniac by itself

gradually added to a quantity of water, will occasion a considerable refrigeration, so that a bottle of wine, &c. placed in the solution may be cooled even to 32° of Fahrenheit's scale. But a mixture of both salts is much more efficacious, and the best proportion is five parts of nitre, five of salt ammoniac, and 16 of water. During the solution, which will continue a considerable time, this mixture will cool the thermometer several degrees below the freezing point; but it must not be imagined that a small quantity of the same will cool a bottle of wine to an equal degree. The solution of a given quantity of the mixture absorbs a certain quantity of heat, and this quantity abstracted from the small body of the thermometer, will lower its temperature considerably; but the same quantity of heat abstracted from a bottle of wine, will cool it proportionably less than the thermometer. In order to cool a bottle of wine from the usual temperature of spring waters (which in London is about 50° or 51°) down to about 32°; a pound of nitre with a pound of salt ammoniac, and a proportionate quantity of water, will generally suffice. The salts for this purpose must be finely powdered and as dry as possible. But when a moderate refrigeration is required; half a pound of each salt and about three pints of water will be sufficient.

Glauber salt, (*viz.* sulphate of soda) dissolved in water, likewise produces a very considerable refrigeration; but this salt will not produce that effect unless it be in its crystallized state. In that state, however, it is not easily preserved, since the mere contact of air will render it powdery and opaque, in which case its solution will generate heat rather than cold. On this account, therefore, this salt is not so much to be recommended, as those which have been already mentioned. Nearly the same observations are applicable to the muriate of lime, the solution of which saline substance, when properly conducted, has a very powerful cooling property.

Thus we have described all the practicable processes of cooling, which, if not in this country, are undoubtedly of great consequence amongst the inhabitants of warmer climates. We have, likewise, stated the most necessary particulars respecting the quantity of materials proportionate to the effect, whence the intelligent reader may be enabled to make proper choice of a process fit for his purpose, agreeably to the circumstances which the nature of the place, the actual temperature of the atmosphere, and other particulars, may offer.

There are now two other particulars belonging to the present article which deserve to be briefly mentioned. The first is that by cooling, certain bodies acquire electrical properties; and the second is that the law of cooling, or progress of refrigeration, furnishes a method of measuring such high degrees of heat, as exceed the scale of ordinary thermometers.

With respect to the first, it has been observed that sulphur, in cooling after having been melted, becomes electrified, so as to attract and repel small light bodies like any other excited electric. The same thing also takes place with wax, chocolate, and a few other substances. Besides this effect of cooling after fusion, there are certain solids, like the tourmalin, the Brazilian emerald, &c. which are rendered electrical by any alteration of their temperature, be it from cold to heat, or from heat to cold; but for a full and particular account of those facts, which properly belong to the science of electricity, see the articles ELECTRICITY, ELECTRICS, and EXCITATION.

The method of determining high degrees of heat, from the progress of cooling, depends upon the following observation. Sir Isaac Newton, considering the progress of cooling, was led to suppose, that the heat lost by any body originally at a high temperature, in equal small portions of time, is as the heat existing in it; (reckoning the heat in the body, equal to its excess above that of the surrounding atmosphere,) that is, taking the times in arithmetical progression. The portions of heat lost in those times would be in a geometrical one. The truth of this supposition has been sufficiently shewn by subsequent experiments, the result of which has not differed much from the theoretical determinations. Hence we have the following practical rule for determining the high temperature to which a body has been exposed, from its subsequent progress of cooling.

Measure the time in minutes that elapses from the hottest state of the body (which is the degree sought,) to such a state of lower temperature as will allow the application of a common thermometer to the body in question, and call this number of degrees A; then having applied the thermometer, set down the temperature, which is indicated by the same, at the expiration of each successive minute, until you have obtained three or four terms of the series, which, as has been said above, will be found to be a geometrical one (omitting, however, trifling differences.) Now, since from those few terms it is easy to determine any other terms of the same series, by the well known arithmetical rules; find so many terms of the series ascending, as are equal to the number of units in A; and the last term of the series, thus found, will be the degree of temperature of the body in its hottest state. An example will easily illustrate the application of this rule. Suppose it be required to determine the temperature of a piece of red-hot iron at the time that it came out of the forge. Look at the watch the moment the iron is taken out of the fire, and note the minute. Find by trials when the thermometer may be safely applied to the iron, *viz.* when the heat is not sufficient to rarefy the mercury of the thermometer beyond the limit of its scale, and when this is practicable, observe the temperature of the iron, and the corresponding time as indicated by the watch. Suppose, for instance, that when the temperature of the iron was 250°, four minutes had elapsed since the commencement of the observation; therefore in this experiment A is equal to 4. Let the thermometer continue in contact with the iron, and when one minute more has elapsed, let the temperature be 125°. When another minute has elapsed, let the temperature be $62\frac{1}{2}$ degrees; and after this, the observation needs not be continued. Now we have three successive terms of a geometrical series; *viz.* $62\frac{1}{2}$, 125, and 250; from which four more terms of the series are to be found, (since A was found equal to 4,) and the last of those terms is the number of degrees indicating the temperature sought. By dividing 250 by 125, or the latter by $62\frac{1}{2}$, we have the quotient 2, (or nearly 2) which is the multiplier of the series, and therefore multiplying 250 by 2, we have the term 500, which multiplied by 2, gives the next term 1000, which multiplied by 2, gives 2000; and lastly this term multipled by 2, gives the fourth term 4000; hence we conclude, that when the iron was taken out of the furnace, its temperature was 4000 degrees. The last term of the series may be found out by other means, but we have chosen the easiest, for the conveniency of all readers. The two series are annexed.

Time elapsed in minutes.	Corresponding heat.
0.	4000°.
1.	2000.
2.	1000.
3.	500.
4.	250.
5.	125.
6.	62½.

Instead of minutes, the intervals of time may be half minutes, or hours, or, in short, of any other denomination; provided they be all equal.

Cooling *of liquors*, in *Domestic Economy*, is a practice of ancient origin, and of general prevalence in warm countries, and, during the heat of summer, even in colder climates. This practice, as some have thought, is referred to by Solomon, in the book of Proverbs (ch. xxv. 13.); but however this be, evidences of it are very numerous in the works of the Greeks and Romans. Ice and snow were generally used for this purpose, and repositories were constructed for keeping these cooling materials. That the snow was preserved in pits or trenches is asserted by many; particularly by Seneca (Quæst. Natur. iv. 13) and Pliny (H. N. l. xix. 4.) When Alexander the Great besieged the city of Petra, he caused thirty trenches to be dug, and filled with snow, which was covered with oak-branches, and which was kept in that manner for a long time (Athenæi Deipnos. iii. p. 124.) Plutarch says (Sympos. vi. Quæst. 6.), that a covering of chaff and coarse cloth is sufficient; and a like method is now practised in Portugal. Where the snow has been collected in a deep gulph, some grass or green sods, covered with dung from the sheep-pens, are thrown over it; and under these it is so well preserved, that it is sent through the whole summer for the distance of 60 Spanish miles to Lisbon. When the ancients wished to have cooling liquors, they either drank the melted snow, or put some of it in their wine, or they placed jars filled with wine in the snow, and suffered it to cool there as long as they thought proper. The dissipated and luxurious Heliogabalus caused whole mounts of snow to be heaped up in summer to cool the air (Lamprid. Vit. Heliogab. c. 23.) That ice was also preserved for the like purpose is probable from the testimony of various authors, Pliny, Seneca, &c.; but it appears not to have been used so much in warm countries as in the northern. At present snow is employed in Italy, Spain, Portugal; but in Persia, ice. The art of cooling water without snow or ice was soon suggested to mankind, by observing, that it became cold more speedily when it had been previously boiled, or at least warmed, and then put in a vessel among snow, or in a place much exposed to the air. Pliny (H. N. l. xxxi. 3. 23.) seems to ascribe this to the invention of Nero; and a jocular expression of Suetonius (Vit. Ner. c. 48.) renders it probable, that he was fond of water thus cooled. But this method was much more ancient than Nero; for it seems to have been known to Hippocrates (De Morb. Vulgar. lib. vi. 4.); and Aristotle was acquainted with it; for he says (Meteorol. i. cap. 12.) that some were accustomed, when they wished water to become soon cold, to place it first in the sun and suffer it to become warm. He relates also, that the fishermen near the Black Sea poured boiling water over the reeds, which they used in fishing on the ice, to cause them to freeze sooner. See also Galen, in lib. vi. Hippocrat. de Morb. Vulg. Comment. 4. 10. Athenæus remarks (Deipnos. iii.) that the pitchers filled with water, which had become warm by standing through the whole day in the sun, were kept continually wet during the night, by servants destined to that office, and in the morning they were bound round with straw. In the island Cimolus, water which had become warm in the day-time was put into earthen jars, and deposited in a cool cellar, where it became as cold as snow. From these facts it appears to have been a general opinion, that water which had been warmed or boiled, was soonest cooled, and acquired a greater degree of refrigeration. The same opinion prevails at present in the southern countries of Asia, and persons there let their water boil before they expose it to the air to cool. The experiments, however, that have been made on this subject, have given different results. Beckmann (ubi infra) inclines to the opinion, that the cooling of water in ancient times is not to be ascribed so much to the boiling as to the keeping of the jars continually wet, and to the air to which they were exposed. See Congelation and Freezing, and also the preceding article.

Another method of cooling water seems to have been known to Plutarch. It consisted in throwing into it small pebbles or plates of lead (Sympos. vi. 5.)

The practice of cooling liquors, at the tables of the great, was not usual in any country besides Italy and the neighbouring states, before the end of the 16th century. In the middle of that century, there were no ice-cellars in France. Towards the end of this century, under the reign of Henry III., the use of snow must have been well known at the French court, though it appears that it was considered by the people as a mark of excessive and effeminate luxury. Towards the end of the 17th century, this luxury must have been very common in France. At that period there were many who dealt in snow and ice; and that was a free trade which every one might carry on: but soon after government farmed out a monopoly of cooling waters.

The method of cooling liquors by placing them in water, in which salt-petre has been dissolved, could not be known to the ancients, because they were unacquainted with that salt. This property of salt-petre was first discovered in the first half of the 16th century; and it was not remarked till a long period afterwards that it belongs also to other salts. The Italians were the first persons by whom it was employed; and about the year 1550, all the water, as well as the wine, drunk at the tables of the great and opulent families at Rome, was cooled in this manner. Towards the end of the 16th century this method of cooling liquors was well known. Mr. Beckmann says, that he cannot determine who first conceived the idea of mixing snow or ice with salt-petre, and other salts, which increase the cold so much, that a vessel filled with water, placed in that mixture, is congealed into a solid mass of ice, that may be used on the table, but the earliest account of it he has been able to find is in a work of Latinus Tancredus, a physician and professor at Naples, who, in his book, "De Fame et Siti," published in 1607, speaks of this experiment. In 1626 Sanct. Sanctorius, in his Commentary on the Works of Avicenna, relates, that, in the presence of many spectators, he had converted wine into ice, not by a mixture of snow and salt-petre, but of snow and common salt. When the salt, he says, was equal to a third part of the snow, the cold was three times as strong as when snow was used alone. Lord Bacon, who died in 1626, says, that a new method had been found out of bringing snow and ice to such a degree of cold, by means of salt-petre, as to make water freeze. This, he tells us, can be done also with common salt; and he adds, that in warm countries, where snow was not to be found, people made ice with salt-petre alone; but that he had never tried the experiment. Mr. Boyle, who died in 1691, made experiments with various

kinds of salt; and he describes, how, by means of salt, a piece of ice may be frozen to another solid body. Des Cartes says, that, in his time, this was a well-known phenomenon, but highly worthy of attention. Since that period, the art of making ice has been mentioned in the writings of all philosophers, where they treated on heat and cold. Towards the end of the 17th century, the French began to congeal all kinds of well-tasted juices, which were served up as refreshments at the tables of the great and wealthy. This was a grand invention for the art of cookery, and afterwards it became common, especially in the last century, and since that time the confectioners have universally practised it. Beckmann's Hist. of Inventions, vol. ii. See FREEZING and ICE.

Copal

COPAL. This valuable and fingular kind of refin is imported partly from South America, and partly from the East Indies, and like moft of the other refins, is a natural exfudation from a large tree, which hardens in the air.

The beft copal is a hard brittle refin, in rounded lumps of moderate fize, eafily reducible to fine powder, beautifully tranfparent, but often, like amber, containing parts of infects and other fmall extraneous bodies impacted in its fubftance.

The colour of copal is a light lemon yellow, varying to orange; but when diffolved and thinly fpread over any furface, the colour is fcarcely perceptible, and it only gives a fine hard, fmooth, tranfparent glazing. It is this union of hardnefs and tranfparency, with want of colour, that renders copal fo valuable as a varnifh.

Copal unqueftionably belongs to the clafs of refins, but it differs from moft of thefe fubftances in the great difficulty with which it diffolves in alcohol and effential oils, fo as to require great purity of thefe menftrua and particular management.

The three menftrua ufually employed in varnifhing, are alcohol, oil of turpentine, or any other effential oil, and drying linfeed, or other fixed oil. Thefe are ufed fometimes feparately with the varnifh refins, but generally mixed.

We fhall give fome of the proceffes by which copal may be diffolved in each of thefe fubftances.

Alcohol fingly, which fo readily diffolves the other refins, has but little action on copal; for if this refin in fine powder be digefted with the very pureft alcohol, with or without heat, fcarcely any of it is diffolved, and the copal coalefces at the bottom of the veffel into a tough cohefive mafs. But a folution may be effected by the addition of *camphor*, the action of which, upon the refins, has been partly defcribed under that article. With none is it more ftriking than with copal. When the two are feparately powdered and mixed, the copal abforbs the camphor, fwells and foftens into a pafty mafs, which will remain for months of the fame confiftence, without hardening. To make an alcoholic folution of copal, diffolve half an ounce of camphor in a pint of highly rectified alcohol; put it in a glafs veffel over a lamp, and add four ounces of copal in fmall pieces, and continue the heat juft to that degree at which the bubbles may be counted, till the folution is compleat. Part of the copal feparates when cold, but moft of it remains in permanent folution.

It is neceffary firft to diffolve the camphor in the alcohol; for, if the pafty mafs arifing from the mixture of copal and camphor be added to alcohol, the folution will not go on.

A mixture of maftich, elemi, and other refins, will bear a moderate quantity of copal, without being rendered infoluble in alcohol, even without the affiftance of camphor.

To diffolve copal in the effential oils, Mr. Sheldrake has given the following procefs in the Tranfactions of the Society of Arts.

Reduce two ounces of copal to *coarfe* powder; put it into a glafs veffel, and pour thereon a pint of the *very beft* oil of turpentine, with one eighth of fpirit of fal ammoniac, previoufly well fhaken. Cork the glafs, leaving a pin-hole through the cork to allow of the efcape of vapour, and fpeedily heat it to that point at which the bubbles may be counted. Continue this till the folution is complete, taking care not to increafe the heat, otherwife the copal will coalefce at the bottom of the glafs, and the folution will not go on. The veffel fhould not be opened till quite cold. This liquor is of a rich deep yellow when in quantity, but when applied as a varnifh, it is nearly colourlefs. The fpirit of fal ammoniac is not a neceffary ingredient.

Mr. Tingry of Geneva (Painter's and Varnifher's Guide, 1804,) finds that copal may be united to oil of turpentine by the intermede of fome other of the effential oils, particularly oil of fpike and lavender. He gives the following procefs: Take two ounces of oil of lavender, heat it in a glafs matrafs, add thereto an ounce of copal grofsly powdered, and, at different times, ftirring the mixture with a ftick of white wood. When the copal is diffolved, add fix ounces of oil of turpentine, nearly boiling, and ftir the whole thoroughly. This gives a fine gold-coloured liquid, very fit for varnifhing.

Camphor alfo highly affifts the folution of copal, in oil of turpentine, as it does in alcohol, and the fame precaution is neceffary, of diffolving the camphor completely in the oil, before the copal is added. Half an ounce of camphor is fufficient to a quart of the oil, to enable it to take up as much copal as will make a good varnifh.

To unite any of the refins with drying linfeed oil in the compofition of the oil varnifhes, it is neceffary to expofe them to a much greater heat than in the former inftances, that is, not lefs than is fufficient to liquefy the refins. This, however, always gives the refin a certain degree of brown colour, which is often injurious to it when ufed as a varnifh. Copal when melted with as little heat as poffible, and then dropped into drying linfeed oil, diffolves therein with eafe, and this folution mixed with clear turpentine, forms a very fine hard varnifh. To avoid as much as poffible the difcolouration of the copal, Mr. Tingry inclofes it in a kind of wire-cage fufpended in a very flow well-regulated furnace; and, as foon as any portion melts, it falls in drops into the drying oil heated and fet beneath it.

When melted copal is dropped into water, a fmall quantity of oil is feparated, and floats at top, and the refin at the bottom is thereby rendered fomewhat more foluble in the different menftrua.

Copal is liable to be confounded with gum anime, when the latter is very clear and good. The diftinction is of fome confequence, as the anime, though valuable in varnifhing, is much lefs fo than the fineft copal, the varnifh with the former being darker coloured, and not fo hard. Befides the external appearance of each, which is pretty diftinct to a practifed eye, the folubility in alcohol furnifhes an ufeful teft, the anime being readily foluble in this fluid, but the copal fcarcely fo.

Copper

COPPER, *Kupper*, Germ. *Cuivre*, Fr. *Cuprum*, *Aes*. Lat. *Venus*, Alchem.

Copper is a ductile and malleable metal, of a pale yellowish red colour. It is soluble in most acids, and is precipitable from them in the metallic state, by iron or zinc: its oxyd is soluble in ammonia, to which it communicates a bright blue purple colour.

§ 1. *Ores of Copper.*

Sp. 1. Native copper. *Gediegen Kupper. Cuivre natif.*

Its colour is a clear copper-red, often tarnished, externally yellowish, blackish, or whitish.

It occurs in mass, disseminated, in leaves and grains, also capillary, moss-like, dendritical and crystallized. The regular forms that it presents, are the cube, the octohedron, and the pyramidal dodecahedron often with a short six-sided prism interposed.

The crystals are small, and generally implanted in each other, forming clustered masses. Its lustre internally is glistening and metallic; its fracture is hackly: when cut or rubbed, it acquires a high metallic lustre. It is not very hard, is malleable and flexible, but not elastic, is tough and difficultly frangible. Sp. gr. 7.72.—8.53.

It is fusible before the blow-pipe, and appears to be pure copper.

It occurs in veins and beds in various primitive and secondary mountains, accompanied by many of the other ores of copper, also by galena, horn silver, native silver, calcareous, heavy, and fluor spars.

It is very extensively, but not very abundantly, diffused; the largest masses appear to be procured from the copper mine river, within the arctic circle in North America; it is also of frequent occurrence in Japan and Brazil, in Siberia, Hungary, Norway, Sweden, Saxony, and Cornwall.

Sp. 2. Vitreous copper. *Kupperglas. Cuivre vitreux.*

Its colour is dark lead-grey, passing into blackish-grey; it is often covered superficially by a steel-coloured tarnish. It occurs in mass, disseminated or crystallized. The forms of its crystals are the cube, the octohedron, and a hexahedral prism, sometimes terminated by trihedral summits. The crystals are small; externally they are shining, internally they exhibit a glistening metallic lustre. The fracture is fine-grained, uneven, passing into conchoidal. It gives a

shining streak, is blackish when pulverized; is somewhat brittle, and easily frangible. Sp. gr. 4.1.—5.4.

It effervesces with nitrous acid, and when exposed to the blow-pipe, gives a metallic button of a steel-grey colour, and generally attractible by the magnet.

When pure, it appears to be a simple sulphuret of copper, consisting, according to Chenevix, of

81	Copper
19	Sulphur
100	

It is generally however mixed with iron in the proportion of from 3 to 6 *per cent.* A specimen from Siberia was analyzed by Klaproth, and afforded

78.5	Copper
18.5	Sulphur
2.25	Iron
0.75	Silex
100.	

It occurs in veins and beds in primitive and secondary mountains, accompanied by copper pyrites, and other ores of this metal. It is not very abundant, but is found in various places, especially Cornwall, Hungary, Saxony, Norway, and Siberia.

Sp. 3. Variegated copper. *Buntkuppererz.*

Its colour is intermediate between copper-red, and Tombac brown; by exposure to the air it acquires a superficial tarnish, which is first reddish, then violet, afterwards blue, and lastly green. It occurs in mass, disseminated, superficial, or crystallized in octohedrons. Internally it is shining, with a metallic lustre. Its fracture is small, and imperfectly conchoidal, passing into fine-grained, uneven. It takes a polish by friction, and gives a reddish coloured streak. It is soft, somewhat brittle, and easily frangible. Sp. gr. 4.9. 5.4.

It effervesces with nitrous acid, and melts readily before the blow-pipe, without vapour or odour. Two specimens, the one from Hitterdahl in Norway, and the other from Rudelstadt in Siberia, have been analyzed by Klaproth, with the following results.

Hitt.	Rud.	
69.5	58.	Copper
19.	19.	Sulphur
7.5	18.	Iron
4.	5.	Oxygen
100.	100.	

This ore occurs in beds, veins, and disseminated through rocks, for the most part belonging to the class of primitive. It is usually accompanied by vitreous copper, and copper pyrites. It is found in Cornwall, in Hungary, Saxony, Norway, and Sweden.

Sp. 4. Copper pyrites. *Kupferkies. Pyrite cuivreuse.*

Its colour is deep brass-yellow, passing into gold-yellow. Its surface is often iridescently tarnished. It occurs in mass, disseminated, superficial, stalactitical, clustered, reniform and crystallized in tetrahedrons, and the derivative octohedron, and dodecahedron. The crystals are usually very small and imperfect. The surface of the crystals is smooth and shining; that of the other varieties is rough and glimmering. The fracture is coarse or fine-grained, uneven, passing into conchoidal, and imperfectly foliated. It is brittle, and with difficulty gives a few feeble sparks with the steel; it may be readily cut by a knife. Sp. gr. 4.—4.1.

When exposed to the blow-pipe on charcoal, it decrepitates, emits a sulphureous vapour, and melts into a black globule, which, by further application of the heat, acquires the colour and lustre of copper. It does not appear that the crystallized varieties of this ore have been regularly analyzed, and the proportion of its constituent parts cannot be estimated from the other varieties, on account of the iron pyrites, with which they are always more or less mixed. A specimen analyzed by Lampadius afforded

41.	Copper
17.1	Iron
45.1	Sulphur
103.2	

The richer this ore is in copper, the softer it is, and its colour approaches the more to that of gold. It seldom, however, in the large way, affords more than 20 *per cent.* of copper. It may readily be distinguished from iron pyrites (the only substance with which it is likely to be confounded) by the pale brass yellow colour, and superior hardness of the latter.

Copper pyrites is the most abundant, and most generally diffused of any of the ores of this metal. It occurs in veins and beds in primitive, transition, and secondary rocks, in most countries of the world.

Sp. 5. White copper. *Weiss Kuppererz. Mine de cuivre blanche.*

Its colour is intermediate between silver-white and brass-yellow. It occurs in mass or disseminated. Internally it has a slight metallic lustre. Its fracture is small, and fine-grained uneven. It yields readily to the knife, is brittle, and easily frangible. Sp. gr. 4.5.

Before the blow-pipe it yields a white smoak, and an arsenical odour, and melts into a blackish slag. According to Henckel it yields about 40 *per cent.* of copper, the rest being iron, arsenic, and sulphur.

It occurs in veins and beds, in primitive mountains, and is generally accompanied by copper pyrites and vitreous copper.

It is found in Cornwall, Saxony, Silesia, Hungary, Siberia, and Chili in South America.

Sp. 6. Grey copper. *Fahlerz. Cuivre gris.*

Its usual colour is steel-grey, which passes into iron-black and lead-grey; some varieties incline towards yellow and others again present superficial iridescent colours. It occurs in mass, disseminated or investing, or crystallized in regular tetrahedrons and their modifications. The crystals are small, with shining surfaces. Internally it is glistening, or shining with a metallic lustre. The fracture is coarse, and small-grained, uneven, inclining to imperfectly conchoidal. It gives a black or reddish-brown powder. It is moderately hard, brittle, and easily frangible. Sp. gr. 4.46.—4.36.

The only necessary ingredients of this species (as appears from an analysis by Chenevix; of the crystallized variety) appear to be copper, iron, and sulphur in the following proportions, *viz.*

52	Copper
33	Iron
14	Sulphur
99	

The uncrystallized varieties, however, generally contain also antimony, silver, and lead, but in very variable propor-

tions. In feveral varieties from Germany, Mr. Chenevix found antimony varying in proportion from 5 to 38 *per cent.* but neither lead nor filver. Two fpecimens, the one from Andreafberg, and the other from Crannitz, have been analyzed by Klaproth with the following refults.

Copper	31.36	16
Iron	3.3	13
Sulphur	11.5	10
Antimony	34.09	16
Silver	14.77	2.25
Lead	0.	34.
Silex	0.	2.5
	95.02	93.75

Finally, a fpecimen from Piedmont has been examined by Napione, and found to confift of

Copper	29.3
Iron	12.1
Sulphur	12.7
Antimony	36.9
Silver	0.7
Arfenic	4.
Alumine	1.1
	96.8

Thofe fpecimens that give a reddifh-brown ftreak, are generally the moft abundant in filver.

It occurs in veins in flate, and fome other of the neweft primitive rocks, and in beds in the tranfition and floetz rocks. It is accompanied by copper pyrites, galena, manganefe, fpathofe iron, and rarely by malachite. When it contains a notable proportion of filver, it is confidered and worked as an ore of this metal.

It is found in Cornwall, and in the county of Ayr in Scotland; alfo in Bohemia, Hungary, Tranfylvania, Saxony, Heffe, the Hartz, France, Spain, Piedmont, Sweden, Norway, Siberia, and Chili.

Sp. 7. Black copper. *Kupperchwartze. Cuivre noir.*

Its colour is intermediate, between blueifh and brownifh black. It occurs in mafs, diffeminated or invefting. It is compofed of dull moderately cohering particles. It is friable, flightly foils the fingers, is meagre to the feel, and heavy.

Before the blow-pipe it emits a fulphureous odour, and melts into a flag that colours borax green. It has not been regularly analyzed, but is faid to contain from 40 to 50 *per cent.* of copper.

It occurs with other ores of copper, particularly copper pyrites, malachite, mountain green, and vitreous copper.

It is found of remarkable beauty, at Kupperberg, in Silefia, alfo in Saxony, Hungary, Norway, and Siberia.

Sp. 8. Ruby copper. *Roth. Kuppererz. Cuivre oxydé rouge.*

Of this fpecies, there are the three following varieties.

Var. 1. Lamellar.

Its colour is dark cochineal red, inclining fometimes to lead grey; when cryftallized it is often of a full carmine red. It occurs in mafs, diffeminated and cryftallized in cubes, and aluminiform octohedrons. The cryftals are fmall, and for the moft part laterally aggregated; their furfaces are fmooth and fhining. Its internal luftre is more or lefs fhining, and is intermediate between metallic and adamantine. Its fracture is imperfectly foliated, paffing into granular uneven. When in mafs it is ufually opake, or at moft tranflucent on the edges; the cryftals are tranfparent, verging into tranflucent. It gives a brownifh brick-red ftreak, is moderately hard, brittle, and eafily frangible. Sp. gr. 3.95.

By expofure to the blow-pipe on charcoal, it is eafily reducible to a metallic bead, without emitting either odour, or fmoak. It diffolves in the nitrous and muriatic acids, in the former with, and in the latter without, effervefcence. According to Mr. Chenevix, it confifts of

88.5	Copper
11.5	Oxygen
100.	

It is met with chiefly in veins, and appears to be peculiar to primitive mountains. It is accompanied by native copper and other ores of this metal. It is found in Cornwall, in Hungary, Saxony, the Hartz, Siberia, Peru, and Chili.

Var. 2. Capillary.

This variety differs from the preceding in being of a fomewhat lighter colour, fuperior luftre, and being compofed of fmall capillary cryftals and thin flakes.

Var. 3. Compact.

It occurs in mafs and diffeminated, but never cryftallized. Its internal luftre is glimmering, femi-metallic: its fracture is even; and it is opake. In other refpects it agrees with var. 1.

Sp. 9. Tile-red copper. *Ziegelerz.*

This fpecies prefents two varieties, indurated and earthy.

Var. 1. Indurated.

Its colour is intermediate between hyacinth and brownifh-red, paffing on the one hand into lead-grey, and on the other into reddifh-brown. It occurs maffive and diffeminated. The reddifh kind has a glimmering luftre and flat conchoidal fracture; the browner kind has a fomewhat refinous luftre and a fmall conchoidal fracture. It acquires a luftre by friction, is moderately hard and brittle.

When expofed to the blow-pipe it becomes black, and is infufible without addition. Borax is tinged by it of a dirty green. It appears to be an intimate mixture of compact ruby copper with brown iron ochre, and its produce of copper varies from 10 to 50 *per cent.*

It occurs in veins with ruby copper, malachite, copper pyrites, and iron ochre.

Var. 2. Earthy.

Its colour is hyacinth-red, paffing into reddifh or yellowifh brown. Its texture is between friable and folid. It occurs in mafs, diffeminated, and invefting copper pyrites. It is without luftre, has an earthy fracture, and flightly foils the fingers. In its other characters it agrees with the preceding variety.

Sp. 10. Mountain blue. *Kupperlazar. Cuivre carbonaté bleu.*

Of this there are the two following varieties.

Var. 1. Radiated.

Its principal colour is fky-blue, which paffes into Pruffian and indigo-blue. It occurs in mafs, diffeminated or invefting, more frequently botryoidal, ftalactitic, and cellular, but moft frequently cryftallized in oblique rhomboidal prifms or octohedral prifms with dihedral fummits. The cryftals are generally very fmall and aggregated into globular maffes or bundles. The cryftallized varieties are externally fhining, but the reft are dull. Internally it is fhining or glittering, with a luftre between vitreous and refinous. Its fracture is ftraight or divergingly radiated, rarely lamellar. The cryftals are tranflucent and femi-tranfparent, the other varieties

are opake, or at most transflucent on the edges. When pulverized it is of a sky-blue colour. It is soft, brittle, and easily frangible. Sp. g. 3.2.—3.4.

It is very difficult of fusion before the blow-pipe, *per se*; but with borax it gives a bright green glass, and a metallic globule.

According to Pelletier it consists of

66	to	70	Copper
18	—	20	Carbonic acid
8	—	10	Oxygen
2	—	—	Water

Var. 2. Earthy.

Its colour is smalt-blue: it occurs rarely in mass, generally disseminated or superficial: it is composed of fine pulverulent cohering dull particles. Its fracture is fine-grained earthy, passing into even and imperfectly conchoidal. It is opake, slightly stains the fingers, and is easily frangible.

Before the blow-pipe it becomes black, but does not melt. In borax it dissolves with great ebullition, and forms a green glass.

Mountain-green occurs in the newer primitive rocks, but more commonly in floetz mountains. It accompanies other ores of copper, especially malachite, grey copper, and copper pyrites. The most beautiful specimens come from the Bannat in Hungary, and from Siberia. In the Tyrol it is found in sufficient plenty to be manufactured into the pigment called mountain-blue.

Sp. 11. Malachite.

Of this there are the two following varieties.

Var. 1. Fibrous.

Its common colour is grass-green passing into emerald-green, and sometimes into dark leek-green. It seldom occurs massive or disseminated, but generally investing, and often crystallized in short capillary needles, disposed in divergent bundles, or stars. Externally they are shining, but internally only glistening with a silky lustre. Its fracture is delicate, diverging fibrous, passing into coarse fibrous. It is opake or transflucent on the edges; the crystals are for the most part transflucent. When pulverized it retains its colour, only the tint is somewhat lighter. It is very soft, brittle, and easily frangible. Sp. gr. 3.5.

It effervesces with acids, and forms a blue solution with ammonia. Before the blow-pipe it blackens and decrepitates, but is infusible, *per se*. With borax it melts into a green glass. Its constituent parts, according to Klaproth, are

58	Copper
18	Oxygen
12.5	Carbonic acid
11.5	Water
100	

It occurs usually in the newer primitive and floetz mountains, accompanied by other ores of copper, also by carbonat of lead, calcareous spar, brown spar, and quartz. The finest specimens of this variety of malachite are found in the Siberian and Hungarian mines; it occurs also in Saxony and other mining districts in Germany, in Norway, and in Shetland, and the counties of Cornwall and Derby in Britain.

Var. 2. Compact.

Its colour is emerald-green passing into grass and verdegris-green, the same specimen exhibiting different shades of colour: its external surface is commonly overspread with a greenish-white crust. It occurs massive and disseminated, but most frequently reniform, botryoidal, mamillated, stalactitic, or globular. Externally it is rough and dull; internally it is, according to the fracture, either dull, glistening, or shining. Its fracture is conchoidal, or fine-granular uneven, or minutely fibrous. It generally occurs in thin lamellar concentric distinct concretions, each of which has usually a different shade of colour. It is opake, soft, brittle, and easily frangible. Sp. gr. 3.5.—3.6.

Its chemical characters and component parts are nearly the same as those of the preceding variety, with which it also agrees in its geognostic and geographical situation.

Its beautiful colour, lustre, and the high polish that it is capable of receiving, render it much sought after for various ornamental purposes: it would however be much more esteemed if it was harder.

Sp. 12. Mountain-green. *Kuppergrün. Vert de cuivre.*

Its colour is verdegris-green, passing occasionally into emerald-green and sky-blue. It occurs in mass, disseminated or investing. Internally it is shining passing into glittering, with a resinous lustre. Its fracture is small conchoidal. It is transflucent and semi-transparent; is soft and easily frangible.

Its chief chemical character is that of giving little or no effervescence, while dissolving in acids. It has not been analyzed. It is found in similar situations with malachite, but is of much rarer occurrence.

Sp. 13. Emerald copper. *Kupperschmaragd. Dioptase* of Hauy.

Its colour is emerald-green. It occurs crystallized in lengthened dodecahedrons. It is shining both externally and internally, and has a vitreous lustre. It is transflucent, passing to semi-transparent; scratches glass feebly, and with difficulty; is brittle. Sp. gr. 3.3.

Before the blow-pipe it becomes of a chesnut-brown colour, and is infusible, *per se*. With borax it gives a bead of copper. According to an analysis by Vauquelin it consists of

25.57	Oxyd of copper
42.85	Carbonat of lime
28.57	Silex
96.99	

It has hitherto been found only in Daouria on the Russian and Chinese frontiers in a vein accompanied by malachite.

Sp. 14. Micaceous copper. *Kupperglimmer.*

Its colour is deep emerald-green passing to verdegris-green. It occurs massive, disseminated, and crystallized in hexahedral tables. Externally it is smooth and shining with a pearly lustre. Its fracture is foliated. It is transflucent passing into semi-transparent. It is softer than calcareous spar. Sp. gr. 2.54.

It decrepitates strongly when suddenly heated, and is composed, according to Chenevix, of

58	Oxyd of copper
21	Arsenic acid
21	Water
100	

It is found in Huel Gorland mine in Cornwall, in veins accompanied by vitreous copper, copper pyrites, arsenical pyrites, and iron ochre.

Sp. 15. Octohedral arseniat of copper. *Linsenerz* of Werner.

Its colour is deep sky-blue, passing into Prussian-blue, blueish-white, apple-green, and grass-green. It occurs in obtuse pyramidal octohedrons. The crystals are small and aggregated into clusters; they have a shining vitreous lustre,

and a lamellar fracture, are semi-transparent passing into transparent. In hardness they are inferior to fluor spar. Sp. gr. 2.88.

It is composed, according to Chenevix, of

49	Oxyd of copper
14	Arsenic acid
35	Water
98	

It is found in the same mine as the preceding species.

Sp. 16. Foliated arseniat of copper. *Blattriges olivenerz* of Werner.

Its colour is olive-green, passing to oil and leek-green. It occurs rarely massive, and generally crystallized in acute rhomboids and oblique quadrilateral prisms. The surfaces of the crystals are smooth and shining. Internally it is glistening and shining, with a diamond lustre. Its fracture is imperfectly foliated. It is translucent passing into transparent. It is somewhat harder than calcareous spar. Its component parts, according to Chenevix, are,

54	Oxyd of copper
30	Arsenic acid
16	Water
100	

It is found in the same mine with Sp. 14.

Sp. 17. Fibrous arseniat of copper. *Fasriges olivenerz.* Werner.

Its colour is brownish, or dark bottle green, passing into yellowish; when capillary it is of a lighter and brighter colour. It occurs crystallized in an irregular acute octohedron, or a long compressed hexahedral prism, or capillary. Sometimes the crystals are regular at one extremity, and terminate in capillary brushes at the other. The crystals are small and laterally aggregated. It has a considerable lustre between vitreous and resinous, is translucent passing to transparent; is harder than fluor spar, but will not scratch glass. Sp. gr. 4.28. It passes into the two following varieties.

1. Amianthiform.

Its colour varies from blueish-green to grass-green, brown-green, straw-yellow, and white. It occurs in extremely minute parallel, or diverging flexible fibres, or thin dusty flexible laminæ, with more or less of a sattiny lustre.

2. Hæmatitiform.

Its colour is brownish or whitish-yellow. It occurs in flat or mamillated layers, either smooth or varied with small rough crystalline points.

Its texture is fibrous but very compact, resembling wood-tin.

The above species, with its varieties, has been analyzed by Mr. Chenevix, with the following result:

Prismatic.	Capillary.	Hæmatiff.	
60.	51.	50.	Oxyd of copper
39.7	29.	29.	Arsenic acid
0.	18.	21.	Water
99.7	98.	100.	

It is found in Huel Gorland mine, in Cornwall.

Sp. 18. Phosphat of copper.

Its colour is, externally, greyish-black; internally, between emerald and verdegris-green. It occurs in mass, disseminated and crystallized in rhomboids. The crystals are small and very small; their lustre is externally vitreous and shining. Internally, it is glistening with a silky lustre. Its fracture is fine and diverging fibrous. It is opake, and moderately hard. It consists, according to Klaproth, of

68.13	Oxyd of copper
30 95	Phosphoric acid
99.08	

It has hitherto been found only at Firneberg in Cologne, in white drusy quartz.

Sp. 19. Sandy copper. *Saltzkupfererz.* Werner.

Its colour is emerald-green, passing into leek and olive-green. It occurs massive, disseminated, and crystallized in extremely minute six or four-sided prisms. The surface of the crystals is smooth and brilliant, and their fracture lamellar. The massive variety is opake; the crystals are transparent. It is soft and easily frangible. Sp. gr. 4.43.

Before the blow-pipe on charcoal, it tinges the flame of a bright green and blue colour, and a metallic globule remains behind. It is soluble in nitrous acid, without effervescence. The following are its constituent parts, according to Proust and Klaproth.

Proust.		Klaproth.	
From Peru.	Chili.	Chili.	
76.595	70 482	73.	Oxyd of copper
10.638	11.446	10.1	Muriatic acid
12.767	18.072	16.9	Water
100.	100.	100.	

It is found loose in the bed of a river at Kernolinos, in Chili, and elsewhere, though rarely in Spanish South America.

§ 2. *Assay and Analysis.*

The assay of copper ores, (though by no means so accurate a method of ascertaining their metallic contents as a regular analysis) being the method by which the market price of the ore is always determined, requires the first notice. The best method, upon the whole, of conducting it, is as follows.

First, expose a small piece of the ore, under examination, to the action of the blow-pipe, and by the appearance and odour of the vapour given out, it is easy to discover whether it contains any arsenic or sulphur. It may very probably contain both, in which case, take 300 grains of the ore coarsely pulverized, mix it with half its weight of sawdust, and keep it at a moderate red heat in an earthen crucible, till the disengagement of arsenical vapour entirely ceases. Then pour the contents of the crucible into an iron mortar, and reduce them carefully to a fine powder. Transfer this powder to a test, and expose it to a good red heat, with occasional stirring, till both the charcoal and sulphur are burnt off. The residue is then to be accurately mixed with $\frac{1}{12}$ of its weight of lamp-black, half its weight of *pulverized* glass of borax, and a drop or two of oil; the mass thus formed, is to be put into a sound earthen crucible, a cover is to be luted on, and the whole is to be placed in a good wind furnace. The heat should be moderate for the first quarter of an hour, to allow the borax time to combine with the earthy impurities of the ore; then a moderate white heat is to be applied for about twenty minutes. After this, the crucible being withdrawn and cooled, is to be care-

fully broken, and will be found to contain a button of copper, covered by vitreous scoriæ. The purity of the copper thus procured, is to be estimated from its colour, softness, malleability, and tenacity; after which, a part of it may be cupelled with pure lead, in order to ascertain whether it holds any silver or gold. If the ore contains sulphur, but no arsenic, it may be mixed with half its weight of charcoal, and roasted on a test, without being previously heated in the crucible. If the ore contains neither sulphur nor arsenic, it should be first moderately ignited in a covered crucible, to drive off any moisture, and may then be treated with borax and lamp black, as already described.

The proper analysis, by means of liquid menstrua, is however much more accurate than even the most carefully conducted assay, and the general mode of proceeding with the ores of copper is, upon the whole, very simple. The copper, together with the other metals with which it may happen to be mixed, is to be separated from the silex and sulphur, by means of an acid, the other metals are then to be got rid of by their appropriate reagents, and the copper is then to be procured either in the state of green carbonat, of black oxyd, or of pure metal; of the first, 180 parts are equivalent to 100 of metallic copper; and of the second, 100 parts contain 80 of metal.

Previously to undertaking an analysis, a part of the specimen, under examination, should be subjected to the usual reagents, in order to ascertain not indeed the proportion, but the nature of the ingredients of which it consists; and, in few cases is this more necessary than in the analysis of the ores of copper, both as they are so numerous and so various in their composition. This previous examination being duly performed, the analysis may be conducted in the following manner:

For the analysis of the *pyritical*, and other *sulphurized ores of copper*, provided they contain neither silver nor lead, take 200 grains of the pulverized ore, and digest it at a boiling heat with muriatic acid, (adding occasionally a few drops of nitric acid) till every thing soluble in this menstruum is taken up. Of the insoluble portion, a part, consisting chiefly of sulphur, will be found floating on the liquor; and this being washed, dried, and weighed, is to be ignited on a test, by which the sulphur will be burnt off, and its amount may be estimated from the loss of weight sustained by the process. The incombustible residue is to be digested in a little warm muriatic acid, and what remains insoluble, is to be added to the other insoluble residue. The muriatic solutions being mixed together, the whole is to be decomposed by carbonated potash, and the precipitate, hence resulting, is to be digested in repeated portions of caustic ammonia, as long as this latter acquires any blue tinge. The whole of the copper, and nothing else, will thus be taken up by the ammonia, from which it may be obtained in the state of black oxyd, by the addition of a little caustic potash, and a boiling heat. The residue, insoluble in ammonia, consists of oxyd of iron, with perhaps a little alumine, which may be separated by caustic potash, the alumine alone being soluble in this fluid. Finally, the portion insoluble in muriatic acid, may be considered as little else than silex.

The ores which, besides *copper*, *sulphur*, and *iron*, contain *silver*, *lead*, and *antimony*, may be thus analyzed. The ore, reduced to fine powder, is to be repeatedly digested with moderately diluted nitric acid, as long as any thing continues to be taken up by this menstruum. To the nitric solution is then to be added muriat of soda, which will throw down the silver in the state of luna cornea; this being separated, the lead is to be precipitated in the form of sulphat, by sulphat of soda; the solution is now to be supersaturated with ammonia, which will dissolve the copper, and eave behind the oxyd of iron, with probably a little alumine and silex. The copper is to be procured from the ammoniacal solution, in the manner directed in the preceding paragraph; and the oxyd of iron may be separated from the admixed earths, by caustic potash. That portion of ore, insoluble in nitric acid, is to be digested in muriatic acid, which will take up every thing except the sulphur, silex, and probably a little luna cornea. Of this insoluble residue, the sulphur is to be burnt off by gentle ignition, and the remainder is to be fused with twice its weight of pearlash, by which the silver in the luna cornea will be reduced to the metallic state. The muriatic solution being concentrated by evaporation, and then poured into a considerable quantity of water, will deposit the antimony in the form of a white oxyd.

The simple *oxyds of copper*, are best analyzed by digestion in nitric acid, and then supersaturating the solution with ammonia, by which any casual admixture of iron will be separated.

The *carbonats of copper* are to be thus treated. One portion is to be gently calcined in a covered crucible, and the loss of weight sustained, indicates the united amount of the water and carbonic acid. A second portion is to be thrown into a known quantity of dilute sulphuric acid, and the loss of weight, by the effervescence which ensues, shows the amount of carbonic acid. The sulphat of copper thus obtained, may be subsequently decomposed, either by a stick of zinc, or by liquid ammonia.

The *arseniats of copper* are most conveniently analyzed by first moderately heating them, in order to drive off and thus estimate the water, and then digesting the residue in dilute nitric acid, by which it will be entirely dissolved; nitrat of lead is then to be dropped in as long as it occasions any precipitate, and this latter being removed, the fluid is to be evaporated nearly to dryness, after which, warm alcohol is to be added, which will take up the whole, except a white powder; this powder, and the precipitate on the addition of nitrated lead, are arseniat of lead, 33.66 *per cent*. of which is arsenic acid. The alcoholic solution is then to be evaporated nearly to dryness, and then to be digested with ammonia, which will take up the copper, leaving behind any oxyd of iron that may have happened to be contained in the ore. The ammoniuret of copper, being decomposed by caustic potash, gives the copper in the state of black oxyd, which is that in which it exists in the ore.

The analysis of *muriat of copper* is very simple. It was thus effected by Klaproth. The ore, being pulverized, was dissolved in cold nitric acid, with the exception of 1.5 *per cent*. of oxyd of iron; the solution being then diluted, nitrat of silver was added, till it occasioned no further precipitate; the luna cornea thus obtained, indicated, according to the known proportions of this salt, the amount of muriatic acid in the ore. The nitrous solution was then decomposed, and the copper obtained in the metallic form, by means of a bar of iron.

Phosphat of copper was thus analyzed by Klaproth. On digestion in nitric acid, the whole was taken up except a few grains of quartz; the excess of acid in the solution was then saturated by potash, and acetite of lead was poured in till it had quite ceased to occasion any precipitate; the phosphat of lead, thus obtained, was separated from the solution, and sulphat of soda was added to decompose and

precipitate the ſmall exceſs of acetite of lead which had been made uſe of. A little ſulphuric acid was then added to the ſolution, and the copper was precipitated in the uſual way, by means of a bar of iron.

§ 3. *Reduction of Ores.*

The only ores of copper that are in fact wrought in the large way, and from which the copper of commerce is for the moſt part ſupplied, are the ſulphureous and arſenical ores of this metal. The method of reducing them, though conſiſting of a great number of proceſſes, on account of the powerful affinity, both of the arſenic and ſulphur, is yet upon the whole very ſimple, being little more than repeated roaſtings and fuſions, till the metal has acquired the neceſſary ductility, for it is never brought to a ſtate of abſolute purity, and the commoner ſorts contain both arſenic and antimony, in ſuch proportions, as to be wholly unfit for alloying with either gold or ſilver.

The rough ore, if ſimply ſulphureous, is broken into pieces not larger than an egg, and ſeparated as much as poſſible from the adhering earthy impurities; after which, it is piled in large kilns, and heat being applied at the bottom, the whole maſs becomes gradually heated, and a large portion of the ſulphur ſublimes out, and may be either collected by proper flues, or allowed to eſcape; this firſt proceſs occupies about ſix months, at the expiration of which time, the evaporation of the ſulphur ceaſes, and when the ore has cooled ſufficiently, it is in a fit ſtate to be ſmelted.

If, however, the ore is largely combined with arſenic, it is not capable of keeping up a long combuſtion of itſelf, nor is the heat thus generated adequate to the expulſion of the arſenic; a ſomewhat different method, therefore, of roaſting muſt be had recourſe to. For this purpoſe the ore is ſtill more carefully dreſſed than in the former caſe, and is reduced to pieces not larger than a hazle-nut. It is then ſpread on the floor of a large reverberatory furnace, and expoſed to a dull red heat, with frequent ſtirring, in order to offer freſh ſurfaces to the action of the flame. The arſenic and ſulphur by this treatment are rapidly driven off, and in about twelve hours the roaſting is completed.

The ore is now transferred into the fuſing furnace, which is a reverberatory of the common conſtruction; a little bruiſed lime-ſtone is generally added by way of flux, and in the courſe of four or five hours the fuſion is uſually complete; the ſlag, now of the conſiſtence of ſoft dough, is raked off, and the copper is diſcharged through a plug-hole into water, by which it is reduced into ſmall drops or grains.

The copper, however, though in the metallic ſtate, is ſtill very impure, being largely mixed with ſulphur and arſenic, which give it a grey colour, and render it perfectly brittle. In order to ſeparate theſe impurities, it is re-melted and granulated twice more or oftener, a conſiderable quantity of ſlag being ſeparated at each fuſion; but as this ſlag contains ſome copper it is not thrown away, but worked over again with the next charge of calcined ore. The number of fuſions and granulations entirely depend on the quantity of impurities, and the obſtinacy with which they combine with the copper; but when theſe proceſſes have been repeated the requiſite number of times, the granulated maſs is melted and caſt into pigs. Theſe again are broken to pieces, and roaſted for one or two days in a low red heat, and again melted and roaſted ſeveral times, till the metal approaches to the ſtate of malleable copper. It is now caſt into oblong maſſes, about 14 inches in length, and is fit for the refining furnace. In this it is again melted, with the addition of a little charcoal, till it acquires the neceſſary degree of malleability, and thus becomes ſaleable copper.

Sometimes lead is employed with good effect in the refining of copper, as it combines with, and ſcorifies iron, and the other eaſily oxydable metals in preference to copper. For this purpoſe the rough copper is ſpread on the floor of a furnace, and when it is in complete fuſion, about 6 or 8 *per cent.* of lead is thrown in, and well mixed with the reſt. In a ſhort time the ſurface of the melted metal becomes covered with a ſemi-vitreous blackiſh brown ſcoria, conſiſting of the mixed oxyds of lead, iron, and other impurities, together with a little copper. The firſt ſcoria being removed, a ſecond is formed, which is in like manner ſcummed off, and ſo on ſucceſſively, till, after ten or twelve hours, the copper is ſufficiently purified: this is aſcertained by the thinneſs of the film with which the melted copper is covered, and by its being of a brick-red colour, alſo by the circumſtance that if a rod of poliſhed iron is dipped into the fuſed maſs the portion of copper that adheres to it immediately falls off when the rod is dipped in cold water.

§ 4. *Chemical and Phyſical Properties.*

The colour of copper is yellowiſh-red; its hardneſs is ſuperior to that of ſilver, but ſomewhat inferior to that of platina; it is very tough, ductile, and malleable; hence it may be beaten into plates or drawn into wire of great ſtrength and compactneſs. It breaks with a hackly fracture. When rubbed, it emits a diſagreeable odour; to the taſte it is nauſeous and ſtyptic. The ſpecific gravity of Swediſh copper, which is the pureſt that is met with in commerce, amounts to about 8.89: that of the commoner ſorts does not exceed 8.6; while that of the Japaneſe copper, on the other hand, amounts, according to Bergmann, to 9.0.

The fuſing point of copper is nearly the ſame as that of gold, namely, a low white heat; before it melts, changeable priſmatic colours appear on its ſurface. When in fuſion, or even at a full red heat, if expoſed to the air, it is ſoon covered with a thin brittle plate of browniſh oxyd, that readily ſeparates from the metal when cold.

This ſubſtance is an imperfect oxyd, and was formerly called *copper aſhes*, *æs uſtum*, or *cinis æris*, and by repeatedly heating and cooling a bar of this metal, the whole may be thus changed. Theſe ſcales, according to Prouſt, are compoſed of about 62 *per cent.* of perfect or black oxyd, and 38 of copper nearly in the metallic ſtate; hence, when they are digeſted in cold dilute ſulphuric acid, only the former portion is taken up. By ſubſequent calcination, the ſcales are wholly converted into black oxyd, the weight of which is one-fourth more than that of the original copper. At a very high heat, this oxyd runs into a bright reddiſh-brown opake glaſs.

Copper, when in high fuſion, and in contact with the air, like all the other eaſily oxydable metals, is actually combuſtible; it burns with a beautiful light green flame; the ſame delicate tinge is viſible when a little of the oxyd, or of any of the ſalts of this metal, is ſtrewed on burning coals. The green flame thus produced depoſits a ſmall portion of greeniſh-grey pulverulent oxyd, and hence it gradually collects as a kind of ſoot in the chimnies of furnaces employed in ſmelting this metal.

Copper ſoon ruſts in a damp air, and becomes covered with a green cruſt of carbonated oxyd, but this coating, by its ſtrong adheſion to the metal beneath, long preſerves it from further alteration; hence it requires a length of time, and the concurrence of circumſtances peculiarly unfavourable to preſervation, in order to corrode entirely a thick plate of

this metal. Water is not decomposed by copper even at a white heat.

With the exception of a few cases, that will be mentioned presently, copper appears to unite very uniformly with the same proportion of oxygen, forming (when uncombined with water and every other substance) a brownish-black oxyd, of which one-fifth, or 20 *per cent.*, is oxygen, and the remainder copper. This oxyd is produced, as has been already mentioned, by boiling the precipitate from any of the cupreous salts by an alkali, or the ammoniuret of copper, with caustic potash or soda.

Copper, or rather its oxyd, combines with every acid, forming salts, many of which are both curious and important.

Sulphuric acid acts upon metallic copper only when concentrated and boiling hot. For this purpose take copper filings, or thin sheet copper, put it into a glass vessel with twice its weight of strong sulphuric acid, and heat the mixture. As soon as it begins to boil, much sulphureous acid gas is given out, and at length the whole dissolves into a dark-coloured liquor, which, by dilution with water, becomes of a fine blue. If common copper is used for this purpose, there always remains a black sediment, which consists for the most part of sulphuret of copper. If the pure carbonated oxyds are employed, instead of the metal, they will be found to be soluble even in cold and diluted sulphuric acid. The solution, in whichever way it is formed, deposits, by evaporation and gradual cooling, rhomboidal crystals of a deep sky-blue colour, which are sulphat of copper, the *blue* or *Roman vitriol* of the shops.

The same salt is also met with native in copper mines, partly crystallized, but more generally dissolved in the water which drains more or less into all mines. When native, it appears to be formed in consequence of the iron pyrites being first vitriolized, and the resulting sulphat of iron re-acting on the copper.

Sulphat of copper has a very strong, styptic, somewhat acidulous, and excessively nauseous taste. It is soluble in about four times its weight of water. When dried at a heat not exceeding that of boiling water, it loses, according to Proust, about 36 *per cent.*, which is mere water, after which the residue, which is a white pulverulent mass, is again soluble and crystallizable, as at first. But if it is calcined with a strong white heat, the acid itself is expelled without undergoing decomposition, and at length there only remains black oxyd of copper, in the proportion of 32 *per cent.* of the original crystallized salt. Hence 100 parts of sulphat of copper consist, according to Proust, of

Copper	25.6	forming black oxyd	32
Oxygen	6.4		
Sulphuric acid			32
Water			36
			100

Bergmann's analysis of this salt nearly agrees with that of Proust in the proportion of copper (26 *per cent.*); but of the other ingredients he reckons 28 of water, and 46 of acid.

Besides the common sulphat, Proust describes a *sub-sulphat* of copper. This is prepared by adding to the common sulphat some caustic potash, but not sufficient entirely to decompose it. A green precipitate is in consequence deposited, which is the sub-sulphat in question. This salt loses by distillation only 14 *per cent.* of water. The residue, boiled with caustic potash, gives 68 *per cent.* of black oxyd; hence its component parts are

Copper	54.4	68
Oxygen	13.6	
Sulphuric acid		18
Water		14
		100

Sulphat of copper is decomposed by the alkalies, whether pure or carbonated. If either of the fixed alkalies in their caustic state is made use of, the precipitate is not, as might be supposed, a simple oxyd of copper, but that peculiar combination first discovered by Proust, and named by him *hydrat of copper*. It is thus prepared: to a cold solution of sulphat of copper add liquid potash, also cold, to complete saturation; a *blue* precipitate falls down, which, when thoroughly washed with boiling water, is the pure hydrat. Its consistence, when dried at a heat not exceeding 212° Fahr., is nearly that of Prussian-blue; at a somewhat higher temperature it shrinks, and is gradually converted into black oxyd, by the evaporation of its water. By dry distillation it is found to give out about 24 *per cent.* of water, and 1 of carbonic acid, which it probably has absorbed from the air while drying: there remain behind 75 parts of black oxyd. If this latter is again moistened with water, it does not return to the state of hydrat. Hence it appears that the hydrat is a true chemical combination of water and oxyd of copper, in the proportion of about one part of the former to three of the latter, and as such enters into the composition of the cupreous salts. The hydrat is decomposable not merely by heat, but also by *boiling* with either of the fixed alkalies.

Carbonic acid and oxyd of copper unite together without difficulty. This combination is found native, forming the mountain-blue, the malachite, and some of the other ores of copper. It may be prepared artificially by exposing the metal to a damp confined air, in which case it constitutes rust of copper; or more expeditiously by decomposing any of the acid salts of copper by a carbonated alkali. A copious bulky precipitate falls down, which, when well washed and gently dried, is a fine powder, of a beautiful pale apple-green colour. One hundred parts of copper dissolved in any acid, and precipitated by carbonated potash or soda, produce invariably 180 of the green carbonat, dried at a boiling-water heat. This carbonat, when distilled by itself, with a heat gradually increased to redness, gives out 10 parts of water, and 46 of carbonic acid; the black oxyd, remaining behind in the retort, amounts to 125 parts, of which 100 are copper, and 25 oxygen.

When hydrat of copper is gently heated with a solution of super-carbonated potash, a portion is dissolved, forming a greenish-blue liquor, whilst the undissolved residue becomes almost as dark in colour as the black oxyd. The solution, if slowly evaporated, yields a singular salt, consisting of 52 *per cent.* potash, 43 carbonic acid, and 5 oxyd of copper. It is crystallizable and slightly deliquescent. A similar salt, with a base of soda, is produced, when this latter alkali is employed instead of potash.

Copper is very readily soluble in nitric acid, even when cold and considerably diluted. Much heat is excited, and a torrent of nitrous gas given out, the liquor becoming of a bright blue colour in proportion as the copper is dissolved. The oxyds of copper are equally soluble in this acid as the metal is, but without the evolution of nitrous gas. When this solution is hastily evaporated to a certain point,

and then ſuffered to cool, it congeals into a deep blue ſaline maſs, which deliquiates rapidly when expoſed to the air. By a ſlow and careful evaporation this ſalt may be obtained in the form of hexahedral priſms, but equally deliqueſcent as the former amorphous variety. If this blue nitrat be evaporated beyond the point at which it would cryſtallize when cold, nitrous gas begins to be produced, and a green ſcaly concretion ſeparates from the thick blue liquor. If the evaporation is here ſtopped, this green matter may be ſeparated by water, either hot or cold, which diſſolves only the undecompoſed blue nitrat. This green ſubſtance is conſidered by Prouſt as a ſubnitrat of copper; that it ſtill contains nitric acid is proved by its ſtill giving out this acid when mixed with ſulphuric acid and heated. By thorough calcination all the acid and water are expelled, and the black oxyd of copper only remains. The proportions of the ſubnitrat, according to the above-mentioned chemiſt, are

Black oxyd of copper	67
Nitric acid - -	16
Water - - -	17

The blue or perfect nitrat, on the other hand, contains only 27 *per cent.* of black oxyd.

Nitrat of copper is very ſoluble in alcohol, to the flame of which it communicates a very delicate green colour.

The decompoſition of this nitrat by tin is ſo violent as in certain caſes to produce actual combuſtion. This forms an amuſing experiment, and was, we believe, firſt diſcovered by Dr. Higgins. It is thus performed; ſpread out a piece of tin-foil four or five inches ſquare, lay in the middle a ſmall heap of the ſolid blue nitrat, ſprinkle the ſalt with a few drops of water, ſpread over it a little tow, then double up the tin-foil round it on all ſides, twiſting it as tight as may be without breaking. In a ſhort time the maſs will feel burning hot, ſmall bubbles of blue liquor will be ſeen oozing through, and will preſently be ſucceeded by a copious eruption of nitrous gas, attended by minute ſparks of fire and deflagration.

A fine blue pigment is prepared from nitrated copper, called *verditer (cendres blues, Fr.)* It is made in quantity by the refiners, who, after the proceſs of ſeparating ſilver from gold by aquafortis, recover the ſilver from its ſolution by means of copper, and thus obtain a reſidue of nitrat of copper. This ſolution is decompoſed by lime (the preciſe method of doing which is kept ſecret), and the produce being made into cakes and dried ſlowly conſtitutes the beſt kind of verditer.

This pigment has been analyzed by Pelletier with the following reſults. It was totally ſoluble in nitric and muriatic acids, with a copious efferveſcence of carbonic acid: when diſtilled by itſelf 600 hundred grains loſt 200, and afforded 2 French pints of carbonic acid together with ſome water. The calcined reſidue was a black powder, which, being fuſed with a reducing flux, yielded a button of pure copper, amounting to about half the weight of the original verditer. A freſh parcel was then treated with ſulphuric acid, which afforded ſulphat of lime, the earth of which formed about 7 *per cent.* of the original verditer. Of the 200 grains loſt by diſtillation, Pelletier conſiders 180 as carbonic acid. Hence 100 parts of verditer contain

Copper	
Carbonic acid	
Water -	
Lime -	
Remains for oxygen	
	100

But in this eſtimate the amount of carbonic acid is by ſome overſight greatly overrated. The quantity obtained from 600 grains was about 2 French pints, the weight of which, according to Lavoiſier, would be only 66 grains: conſequently 100 grains would yield only 11 grains of this acid. The water was obviouſly only eſtimated at random, and as the copper was in the ſtate of hydrat, certainly amounted to much more than Pelletier has allowed for it. The corrected reſults of the above analyſis therefore would be

Copper	50	83.3	Hydrat of copper
Oxygen	12.5		
Water	20.8		
Lime		7.	
Carbonic acid		11.	
		101.3	

which correſponds very cloſely with the quantity analyzed.

The muriatic acid diſſolves copper with difficulty except when concentrated and boiling, and then hydrogen gas is given out. The oxyds, however, of this metal, and eſpecially the green carbonat, are very readily ſoluble in this acid. The colour of muriat of copper when hot or highly concentrated is brown, but by dilution becomes of a graſs-green. By careful evaporation and cooling it cryſtallizes in lengthened rhomboids, and when haſtily evaporated in feathery cryſtals. This ſalt is commonly deliqueſcent, but when both the copper and acid are quite free from iron is permanent in the air. It is readily ſoluble both in water and alcohol; the latter takes up its own weight when boiling, a part of which afterwards ſeparates in a cryſtalline ſtate as the liquor cools. The compoſition of the cryſtallized ſalt is, according to Prouſt,

Black oxyd of copper	40
Muriatic acid -	24
Water - -	36
	100

A dilute ſolution of muriated copper in water makes a kind of ſympathetic ink, which is colourleſs in the cold, becomes yellow by warming, and again loſes its colour on cooling. Beſides the common muriat, the ingenious reſearches of Prouſt have diſcovered a ſecond muriat, in which the copper appears to be at a lower ſtate of oxydation than in the former ſalt. It affords a nearly colourleſs ſolution, and when ſolid is of a greyiſh white; it may therefore without impropriety be called the white muriat of copper. It is prepared from the common muriat by means of muriat of tin, a ſalt remarkable for the eagerneſs with which it abſorbs oxygen from almoſt all the other metallic ſalts. If therefore ſome of this latter is poured into common muriat of copper, a precipitate falls down which is at firſt white, but by ſubſequent expoſure to air paſſes

through different ſhades of violet and blue to black. This precipitate is for the moſt part a muriated ſub-oxyd of copper. On expoſure to a moderate heat it melts like luna cornea. If digeſted in warm muriatic acid it readily diſſolves, and is depoſited, on cooling, in the form of tetrahedral cryſtals. With nitrous acid ſome nitrous gas is given out, which ſhews that the metal was not previouſly ſaturated with oxygen. Another remarkable character of this white muriat is, that when diſſolved in ammonia the ſolution is colourleſs, though, on expoſure to the air, it gradually acquires the ſky-blue colour of common ammoniuret of copper. Its compoſition, according to Prouſt, is

Muriatic acid		24.75
Oxyd of tin		1.
Copper	-	63.
Oxygen	-	11.25

Aſſuming this analyſis as correct, it is obvious that the copper exiſts in a much lower ſtate of oxygenation in this ſalt than in any hitherto mentioned, for in this the oxyd of copper is compoſed of 63 of metal and 11.25 of oxygen, or (reduced to the hundred) of 84.84 copper, and 15.16 oxygen, whereas the black copper, to which all the common cupreous ſalts are reducible by loſs of their acid and water, conſiſts of 80 *per cent.* copper, and 20 oxygen.

There appears to be yet another ſtate of combination of muriatic acid and oxyd of copper, alſo firſt noticed by Prouſt. It is the *ſubmuriat of copper*, differing from the common muriat not by a lower degree of oxygenation in the metal, but in a ſmaller proportion of acid. It is produced by adding a little potaſh (leſs than required for ſaturation) to the green muriat. A green powder falls down, which is the ſubmuriat in queſtion. This ſalt when boiled with potaſh loſes about 28 *per cent.* of its weight, and is reduced to the black oxyd. A ſimilar ſubmuriat is ſaid by the ſame chemiſt to be ſpontaneouſly depoſited when copper is diſſolved in nitro-muriatic acid. The compoſition of this laſt is as follows:

Black oxyd of copper		
Muriatic acid	-	
Water	-	-
		100.

The native green muriat of copper from Peru appears to be nearly in this ſtate.

Copper ſeems to have a ſtronger affinity for muriatic acid than even for the nitric or ſulphuric. Thus, if either the ſolid nitrat or ſulphat of copper be digeſted in muriatic acid a ſolution takes place, and then, on the application of heat, the liquor immediately loſes the blue colour, characteriſtic of theſe two ſalts, and acquires the green of the muriat: alſo by ſlow evaporation muriat of copper is obtained in cryſtals.

Acetous acid has no action on reguline copper, but its oxyd is eaſily ſoluble in this fluid, to which it communicates a beautiful graſs-green colour. There are two ſpecies of acetited copper, the one with an exceſs of baſe, the common verdegris of the ſhops, and the other in which the acid and oxyd are in a ſtate of mutual ſaturation, forming the cryſtallized or diſtilled verdegris.

The manufacture of verdegris is carried on to a conſiderable extent in moſt of the ſouthern provinces of France, and a very exact account, apparently, of the proceſs has been publiſhed by Chaptal, from which the following particulars are extracted.

The materials for this manufacture are the *marc* or cake that remains in the wine-preſs, after the greater part of the juice has been ſqueezed out; and plates of copper of convenient ſize and hammered well, in order to ſmooth the ſurface, that the corroded portion may be readily detached from the reſt.

The marc of the grape is firſt fermented by being laid as lightly as poſſible in a large barrel and moiſtened with common wine, and then ſet in a warm airy place. In a few days, varying according to the heat of the weather, it begins to ſwell, grows hot and exhales a ſtrong odour of vinegar; the fermentation then declines and the marc is fit for uſe. A layer of this is then put into an earthen pot and a plate of copper, previouſly made ſcorching hot, is laid upon it; to this ſucceeds another layer of marc, and then a plate of copper, in regular alternation till the pot is filled, obſerving that both the top and bottom layers are of marc. The mouth of the pot is then looſely ſtopped with ſtraw, and the whole is left at reſt from ten to twenty days.

When the marc begins to whiten the pots are unpacked, and, if the proceſs has gone on well, the copper-plates are found covered with a green cruſt, interſperſed with ſilky green cryſtals. The marc is thrown away; the plates are ſet on end on wooden racks in a cellar, and when dry are dipped in water and again ſet to dry; this is repeated once a week for ſix or eight times, which makes the cruſt of oxyd ſwell and increaſe both in quantity and quality: after which it is ſcraped off by a knife without difficulty. Each pot yields about 5 or 6lbs. of rough verdegris, and the plates will ſerve again repeatedly till they are corroded quite through.

This rough verdegris is further prepared for market by being ground in wooden mortars, and expoſed to the air till it is ſufficiently dry; and in ſo doing it loſes about half its weight.

Verdegris thus prepared, may be conſidered as copper oxydated by the action of the acetous acid, and combined with water, with carbonic acid, and with part of the extractive or mucilaginous part of the marc. It is nearly inſoluble in water and its colour is blueiſh green. If this verdegris is digeſted in diſtilled vinegar it diſſolves readily in this fluid, and by evaporation and cooling a cryſtallized ſalt of a deep green colour may be obtained, which is known in the ſhops by the name of *diſtilled verdegris*. The method in which this valuable ſalt is prepared at Montpellier is as follows. Common vinegar is firſt diſtilled in a copper alembic, and the acid thus produced is put with common verdegris into a copper boiler; when a hot ſaturated ſolution is thus made, it is ſtrained and transferred to another copper evaporating veſſel, where it is boiled down till a ſaline cruſt begins to collect on its ſurface; a light frame of croſs ſticks is now ſunk into the liquor and the fire is put out. On cooling, the acetite of copper cruſts round the ſticks in cluſters of rhomboidal cryſtals of a deep blueiſh-green colour. It requires about 3lbs. of verdegris to make 1lb. of the cryſtallized acetite.

The compoſition of common verdegris is ſubject (as might be expected from the method in which it is prepared) to a conſiderable variation, and this difference is ſtill further increaſed by variations in the way of manufacturing this ſalt. Thus, at Grenoble, verdegris is made merely by diſpoſing plates of copper in a proper room, and moiſtening their

furfaces repeatedly with diftilled vinegar, till the incruftation of oxyd acquires a proper thicknefs. Hence this latter is purer, and approaches nearer to the ftate of cryftallized acetite, than that of Montpellier.

A hundred parts of the verdegris of Grenoble yield, according to Chaptal, by dry diftillation,

Carbonic acid	- - -	9.1
Water weakly acidulous	-	13.05
Strong, and coloured acetous acid		53.95
Left in the retort	Copper - -	20.9
	Charcoal - -	3.
		100.

A like quantity of the Montpellier verdegris afforded

Carbonic acid - - - -	8.
Acetous acid, weak and empyreumatic,	
Copper - - - - -	
Charcoal - - - - -	
	100.'

To the above particulars may be added fome obfervations, by Prouft, on the properties and compofition of this falt.

When common verdegris is put into cold water, it gradually falls to pieces and nearly half of it is diffolved, the remainder is a fine green powder which diffufes itfelf through the liquor and fubfides very flowly. This green powder appears to be pure fubacetite of copper, and when wafhed and dried weighs about 42 *per cent.* of the original verdegris. When fulphuric acid is poured on it, pungent vapours of vinegar are given out. Boiled with potafh it affords 63 *per cent.* of black oxyd; and when diftilled, after all the volatile products have paffed over, there remains about 52 *per cent.* of copper, principally in the metallic ftate. From thefe data therefore the fubacetite appears to confift of

Copper	50.4	forming black oxyd	63
Oxygen	12.6		
	Remains for acid and water		37
			100

With regard to the cryftallized acetite, Prouft found that 39 parts of black oxyd produce, with diftilled vinegar, 100 parts of acetite; and on the other hand, that 100 parts of this falt, when decompofed by boiling with potafh, yield 39 or 40 parts of black oxyd. Hence it is compofed of

Copper	31.2	forming black oxyd	39
Oxygen	7.8		
Acetous acid	- - - - -		61
			100

The diftillation of the cryftallized acetite furnifhes the moft pungent acetic acid, or radical vinegar, as has been already defcribed under Acetous Acid. Acetite of copper, befide being made by direct combination of its ingredients, may be prepared in various ways by double affinity; of thefe the beft upon the whole is the following: Make a cold folution of fugar of lead *(acetite of lead)* in diftilled water, to which add, by degrees, a cold folution of blue vitriol *(fulphat of copper)*, as long as any precipitation takes place; then pour the whole on a filter, and a green liquor paffes through, the fulphat of lead remaining on the filter, in the form of a white powder. The green liquor, being concentrated by evaporation, depofits, by cooling, very pure and beautiful cryftals of acetite of copper.

The natural combinations of copper with arfenic and arfenic acid have already been noticed. With regard to the artificial arfeniats, Scheele difcovered that when arfenic acid is digefted with copper filings, a green folution is formed, and a blue powder, which is alfo an arfeniat, is precipitated. The fulphat, nitrat, and muriat of copper undergo no apparent change, when added to arfenic acid; but the acetite is decompofed, and arfeniat of copper is precipitated. All the cupreous falts, however, are decompofed by arfeniated alkali, and a blue arfeniat falls down. To thefe facts Mr. Chenevix has added the following: If arfeniat of ammonia and nitrat of copper are added, there falls down a blue cryftalline arfeniat of copper. On evaporating the fupernatant liquor, and adding alcohol, another copious depofition of cryftals took place, of a deeper colour than the former, and of a rhomboidal fhape. Each of thefe arfeniats was examined feparately, firft by calcination at a low red heat to expel the water, then by potafh for the black oxyd of copper, and laftly by nitrat of lead for the arfenic acid. By this method, the firft arfeniat was found to confift of

Oxyd of copper -	50
Arfenic acid -	27
Water - -	22
	99

The fecond arfeniat afforded

Oxyd of copper	
Arfenic acid -	
Water -	

Arfenic, in the ftate of white oxyd, combines with oxyd of copper into a pale green powder, called, from its difcoverer, *Scheele's green.* It is prepared in the following manner: Diffolve 24 ounces of fulphat of copper in water, and heat the folution in a copper veffel; alfo boil in another veffel 24 ounces of pearlafh, 11 ounces of white arfenic, and about 3 pints of water: when the whole is diffolved, ftrain each folution feparately through linen, and then add the arfenicated potafh, little by little, to the fulphat of copper, with conftant ftirring: an effervefcence will take place, and then a green powder will be depofited. When the whole is mixed, let it ftand fome hours, then feparate the precipitate by the filter, edulcorate it well with clear hot water, and dry it very gently in a warm room. The above quantity of ingredients will afford about 18¼ ounces of the powder, which may be ufed as a pigment.

Phofphat of copper may be prepared by adding phofphat of foda to the nitrat, or any other readily foluble falt of copper, a blueifh-green fediment falls to the bottom, which dries to a powdery femi-cryftalline mafs. A low red heat turns it brown, and drives off about 15.5 *per cent.* of water: there remains a phofphat of copper, compofed of 35 parts of phofphoric acid, and 49.5 of oxyd of copper.

A ftriking decompofition of nitrat of copper alfo takes place, when a ftick of frefh melted phofphorus is immerfed in a folution of this falt, and expofed to the light. By degrees the copper is precipitated on the furface of the phofphorus, in the metallic falt, and in the form of cryftalline grains.

All the falts of copper are decompofed by the alkalin pruffiats, and the refult is a fediment of a reddifh-brown colour, which, by drying and expofure to the air, acquires a

dark chocolate hue. This pruffiat of copper mixed well with oil, and has been employed with fome fuccefs as a pigment.

Tincture or infufion of galls throws down from all cupreous folutions a precipitate of a dirty yellow colour.

Oxyd of copper is foluble in all the other acids, forming with them, however, falts little known, and of little importance: the predominating colour in all of them is green.

Of the alkalies, neither potafh nor foda have any action on copper or its oxyds, except that already mentioned, of taking away from the hydrat its water of combination, and reducing it to black oxyd.

Ammonia has no action on metallic copper, but diffolves its oxyds without difficulty. The ufual colour of this folution is a deep blue-purple. The moft direct method of preparing it is by digefting together liquid ammonia and any oxyd, or carbonated oxyd of copper: the liquor becomes blue almoft immediately, and its colour deepens till faturation takes place. By flow and careful evaporation, blue filky cryftals of ammoniuret of copper may be procured. This falt, by expofure to the air, gradually lofes its alkali, and abforbs carbonic acid, fo that at length it is wholly converted into green carbonat The *aqua fapphirina* of pharmacy and furgery confifts, for the moft part, of ammoniated copper, to which its colour is owing: it is made chiefly in two ways. The firft is to digeft in a glafs veffel quick-lime, muriat of ammonia, verdegris, and water; the lime decompofes the muriat of ammonia, difengaging the alkali, which, in its turn, decompofes the verdegris, and diffolves the oxyd of copper: hence the clear liquor confifts of ammoniated copper and muriat of lime. The fecond method, where a weaker folution is wanted, is to employ lime-water inftead of lime. Another way of producing ammoniated copper immediately is to fuperfaturate with this acid any of the falts of copper, in confequence of which the firft portions of alkali decompofe the cupreous falt, throwing down an oxyd, and the fucceeding portions rediffolve the oxyd, forming a dark-blue folution. As there is no other metal befides copper and nickel which produces this particular colour, and as the latter of thefe metals is not common, the production of this beautiful tinge, by the addition of ammonia, may be confidered as a very probable indication of the prefence of copper.

A fingular circumftance takes place with regard to ammoniated copper. If a bottle be filled with liquid ammonia, and a few clean copper filings be added, no folution enfues, as long as the bottle is kept clofe corked. But if the bottle be opened for a while, and then fhut again, a folution indeed of part of the copper takes place, but without any change of colour in the liquor: but when the bottle is again opened, the characteriftic blue tinge appears firft at the furface of the folution, and gradually fpreads down to the bottom. If now a few more copper filings be added, and the bottle again corked, the folution will in a fhort time again become colourlefs, and continue fo till it is again expofed to the air. The reafon of thefe changes appears to be the following: copper requires fome, but only a very fmall quantity, of oxygen to be foluble in ammonia; and when in this loweft ftate of oxydation, it forms with ammonia a colourlefs folution, as it forms with muriatic acid a white fub-muriat: but if this folution is expofed to the air, the metal abforbs oxygen, and is thus brought to that ftate in which it tinges ammonia blue; being again fhut up with a few copper filings, the oxygen is partly abforbed by the recently added metal, and reduces the whole to the ftate of white oxyd.

Many of the neutral falts, efpecially the muriats, are capable of oxydating, and, in part, of diffolving copper: this is efpecially the cafe with muriat of ammonia, which, when made into a mafs with copper filings and a little water, and kept warm, prefently converts the copper into a green muriated oxyd.

Copper and fulphur readily unite. If equal parts of copper filings and flowers of fulphur are mixed and heated in a crucible, much of the fulphur burns off; but the remainder melts into a blueifh-black mafs, which is fulphuret of copper. According to Prouft, 100 parts of copper take up in this way 28 of fulphur; fo that the fulphuret is compofed of about 79 of metallic copper, and 21 of fulphur. No oxygen appears to be prefent. This fubftance is more fufible than copper, melting readily at a red heat. By roafting in the open air, the fulphur is expelled: the laft portions, however, adhere with great obftinacy. According to Dr. Thomfon, fulphur and copper filings unite together, by being merely mixed together with or without water, and expofed for a long time to the air.

Hydrofulphureted water, or any of the liquid hydrofulphurets, when added to the folutions of copper, produce a deep blueifh-black precipitate, which is a hydrofulphuret of copper.

Phofphorus is capable of intimate combination with copper. If 8 parts of this metal in filings, 8 of vitreous phofphoric acid, and 1 of charcoal powder, are intimately mixed together, and then put into a crucible, and expofed to an intenfe heat, the phofphoric acid is decompofed by the action of the charcoal, and the phofphorus in part burns off, and in part unites with the copper, forming a hard, fteel-grey, brittle alloy, capable of a high polifh. A fimpler way of preparing the fame is to make copper filings red hot in a crucible, and project upon them fmall pieces of phofphorus, which combines with the metal, and melts down into a grey mafs, fimilar to the former. One hundred parts of copper may thus be increafed to about 120; but if this phofphuret is kept for fome time melted under charcoal powder, or melted glafs, part of the phofphorus burns off. When this excefs is thus got rid of, the ingredients of the remaining phofphuret appear to be in a ftate of mutual faturation, no more phofphorus being diffipated by a continuation of the fufion. In this ftate the mafs appears to confift of 92.3 of copper, and 7.7 of phofphorus: it retains the grain and colour of fteel, is fufceptible of a high polifh, and does not readily tarnifh in the air, but is brittle. With a ftill lefs proportion of phofphorus, it becomes malleable, and of a yellowifh-white colour. Phofphuret of copper, if kept in fufion, with free expofure to the air, lofes gradually moft of its phofphorus, which burns away with the bright flame and odour peculiar to this fubftance.

The fixed oils, when kept long in contact with copper, oxydate it, and diffolve a portion, by which they acquire a green colour.

The ufes of copper, in its various ftates, are fo numerous and important, as to be fcarcely inferior to thofe of iron. All the falts of copper are more or lefs poifonous, producing violent naufea, with fevere pain and inflammation of the inteftinal canal. Yet from the fudden vomiting that they excite, a large dofe may be given with fafety; and this is fometimes done, when there is an immediate neceffity of emptying the ftomach. Copper, however, is very little ufed medicinally in any form.

§ 5. *Alloys of Copper.*

The alloys of copper are, upon the whole, of more importance than thofe of any other metal: we fhall, therefore, treat of them with fome minutenefs.

Copper with gold and filver.

Copper, when added in ſmall quantity to either of theſe metals, greatly increaſes their hardneſs, without materially debaſing their colour or malleability: hence it has been generally adopted as the alloy for that portion of the precious metals which is employed with current coin, and for plate.

Copper with arſenic.

On account of the volatility of arſenic ſome precautions are required in the preparation of this alloy. The beſt way, upon the whole, is to melt ſome copper in rather a large crucible, and then to wrap up in paper ſome reguline arſenic, or white arſenic, either with or without a mixture of charcoal powder, and to immerſe the paper, with its contents, in the melted copper, either by means of a pair of long tongs, or by ramming the paper into a ſmall crucible, and then inverting the crucible in the fluid metal. The arſenic preſently riſes through the copper in denſe white fumes, and is in a great part diſſipated; a portion however is retained by the copper, and by repeating the proceſs once or twice more, the alloy will be fully ſaturated with arſenic.

This alloy is of a ſilvery white colour and a cloſe texture; it is however very brittle, and, in proportion to the perfect whiteneſs of its colour, liable to tarniſh in the air. As ſoon as it is brought to fuſion the arſenic begins to eſcape, and the copper regains its malleability: the laſt portions however of arſenic are not driven off even by long continued heat, and although the copper regains its malleability, its colour remains of a dingy yellow.

Vauquelin has diſcovered that if to an alloy of copper and ſilver, in equal proportions (the colour of which is a pale yellow), there be added 2 *per cent.* of arſenic, the reſult is a perfectly white ductile and malleable alloy. If this latter ingredient exceeds 5 *per cent.* the alloy begins to be brittle.

Copper with iron.

Theſe two metals only unite when the former of them is greatly in exceſs. The reſult is a hard, grey, and ſomewhat brittle alloy. According to Mr. Keir, the *tutenag* of the Chineſe is a white alloy of copper, zinc, and iron: it is hard, tough, and ſufficiently malleable to be wrought into candleſticks and various other articles of domeſtic furniture, which take a high poliſh, and are ſcarcely to be diſtinguiſhed from ſilver. The inferior ſort of tutenag has, however, a very perceptible braſſy tinge.

According to Dizé, the alloy of iron and copper only ceaſes to be acted on by the magnet, when the proportion of the former is leſs than $\frac{1}{76}$ of the whole maſs. Iron is much inferior in its power of whitening copper to tin or even to arſenic.

Copper with lead.

Theſe metals unite, to appearance, very intimately by fuſion; but when a maſs of this alloy is expoſed to a very low red heat, the greater part of the lead, with a ſmall portion of copper, ſweats out, leaving the reſt in a porous honeycombed ſtate. When the copper holds a little ſilver, the lead carries the latter out with it: this proceſs is called *eliquation*, and will be treated of more at large in the article Silver. Copper, with about a fourth of its weight of lead, forms *pot-metal*. The Roman pot metal was compoſed, according to Pliny, of 100 parts copper, 2 lead, and 2 tin. The ſame ingredients, but with larger proportions of the two latter, were the materials of many of the ancient Greek and Sicilian coins, as appears from analyſes of them by Klaproth.

Copper with zinc.

Copper, when nearly ſaturated with zinc, that is, when the latter amounts to about one-fourth of the alloy, forms *braſs*, of which an account has been already given. With a ſmaller proportion of zinc, the colour of the alloy approaches more nearly to that of gold, and its malleability increaſes. Mixtures, chiefly of theſe two metals, are employed to form a variety of gold coloured alloys, known by the names of *tombac*, *Manheim* or *Dutch gold*, *tinſel*, *ſimilor*, *prince Rupert's metal*, *pinchbeck*, &c. the preciſe compoſition of which varies according to the fancy or experience of different artiſts. The Dutch gold may be beaten into extremely fine leaves, which when freſh are a cheap and good imitation of gold leaf; but they tarniſh very ſoon. The mixture may be made either by melting together copper and zinc, or copper and braſs. In either caſe the copper ſhould be melted firſt, and the other ingredient added afterwards: being then carefully ſtirred together with a ſtick, the alloy is to be poured out into proper moulds without loſs of time, leſt the zinc ſhould burn off.

A fine malleable tombac may be made with 16 parts of copper, one of zinc, and one of tin; if a larger proportion of this latter is added, the alloy becomes harder and brittle. Several Roman coins ſtruck during the firſt century of the emperors, have been analyzed by Klaproth, and appear to conſiſt, ſome of nearly pure copper, others of copper, with from a fifth to a ſixth of zinc. A little tin and lead were found in ſome, but in ſuch ſmall proportions as to appear only an accidental impurity.

Copper with tin.

The alloy of copper and tin are extremely important in the arts, and curious as chemical mixtures. Tin added to copper makes it more fuſible, leſs liable to ruſt or be corroded by the air and other common ſubſtances, harder, denſer, and more ſonorous. In theſe reſpects the alloy has a real advantage over unmixed copper; but this is in many caſes more than counterbalanced by the great brittleneſs which even a moderate portion of tin imparts, and which is a ſingular circumſtance, conſidering how very malleable both metals are before mixture.

The ſenſible qualities of the different mixtures of theſe two metals are the following: Copper, alloyed with from one to five *per cent.* of tin, is much harder than before; its colour is yellow, with a caſt of red, and its fracture is granular: it is ſtill conſiderably malleable. This appears to be the uſual compoſition of many of the ancient edged tools and weapons before the uſe of iron; whence it appears that the ancients did not poſſeſs (as has often been ſuppoſed) any peculiar art of hardening pure copper, otherwiſe than by mixture. An alloy in which the tin is from $\frac{1}{10}$ to $\frac{1}{8}$ of the whole is hard, brittle; but ſtill a little malleable, cloſe-grained, and yellowiſh-white. When the tin is as much as $\frac{1}{6}$ of the maſs, it is entirely brittle, and continues ſo in every higher proportion. The yellowneſs of the alloy is not entirely loſt till the tin amounts to $\frac{7}{23}$ of the whole.

Copper (or ſometimes copper with a little zinc) alloyed with as much tin as will make from about $\frac{1}{10}$ to $\frac{1}{5}$ of the whole, forms an alloy which is principally employed for bells, braſs cannon (ſo called), bronze ſtatues, and various other purpoſes. Hence it is called *bronze* or *bell-metal*, and is excellently fitted for the uſes to which it is applied by its hardneſs, denſity, ſonorouſneſs, and fuſibility. For cannon a lower proportion of tin is commonly uſed. According to Dr. Watſon, the metal employed at Woolwich conſiſts of 100 parts of copper, and from 8 to 12 of tin; hence it retains ſome little malleability, and therefore is tougher than it would be with a larger portion of tin. A common alloy for bell-metal is 80 of copper and 20 of tin; ſome artiſts add to theſe ingredients zinc, antimony, and ſilver, in

ſmall proportions, all of which certainly improve the ſonorouſneſs of the compound.

When in an alloy of copper and tin, the latter metal amounts to about ⅓ of the maſs, the reſult is a beautifully white alloy, with a luſtre almoſt equal to that of mercury, extremely hard, very cloſe-grained, and perfectly brittle. It takes an exquiſite poliſh, which well adapts it for the reflection of light for all optical purpoſes. It is called *ſpeculum metal*, and, beſides the above ingredients, generally contains a little arſenic, zinc, or ſilver. The application of an alloy, ſimilar to the above, to the conſtruction of mirrors, is of great antiquity, being mentioned by Pliny. From the actual analyſis, by Klaproth, of a portion of an ancient ſpeculum, it appeared to conſiſt of

Copper	62
Tin	32
Lead	8

Of theſe ingredients the laſt is conſidered by Klaproth, with high probability, as only a caſual adulteration of the tin.

When the amount of the tin exceeds that of the copper, the alloy begins to loſe its ſplendid whiteneſs, and acquires a blueiſh-grey hue; its texture likewiſe becomes rough-grained, and, as it were, rotten and incapable of receiving a poliſh.

A perfect ſpeculum metal ſhould be quite white, without ſhewing any caſt of yellow when poliſhed, not very liable to tarniſh, quite free from pores, even when examined by a lens, of a certain coherence or toughneſs to bear the grinder, and, for the convenience of working, as ſoft as may be conſiſtent with the other requiſites.

Mr. Mudge, whoſe ſpecula were celebrated for their goodneſs, obſerves, that the extreme of whiteneſs is given by 32 parts of copper and 16 of tin, but this compound is too hard and brittle; 32 parts of copper with 14½ of tin form an alloy quite white, and as hard as can be wrought. In order that the metal ſhould turn out free from pores, it ought to be twice fuſed, once for mixture of the ingredients, and afterwards, with as little heat as poſſible, for caſting.

The following obſervations on the ſame ſubject are extracted from an elaborate paper by Mr. Edwards, publiſhed in the Nautical Almanack for 1787.

The quality of the copper ſhould firſt be tried by adding ſucceſſively from ſo much ſhort of half of its weight of tin, that the mixture proves a little yellow, to the full half of tin, and by compariſon of the various ſamples aſcertaining the *maximum* of whiteneſs. When this is found, take 32 parts of copper, melt it, then add one part of braſs and the ſame of ſilver, with a little black flux to cover the ſurface; when theſe are melted ſtir them together with a wooden rod, and pour in from 15 to 16 parts of tin (as aſcertained by previous experiment) fuſed in a ſeparate crucible, at a low heat; then ſtir the mixture again, and immediately pour it into cold water. Re-melt, with as little heat as poſſible, the alloy thus formed, and for every 16 parts take one of white arſenic, wrap it in paper, thruſt the packet to the bottom of the fluid metal with a wooden rod, and ſtir it well as long as any arſenical vapours ariſe; when theſe ceaſe pour the metal into a mould of ſand, and as ſoon as it has ſolidified lay it in a pot full of very hot embers, and cool it very ſlowly: unleſs this precaution is particularly obſerved, the metal will fly in pieces when cold, or will ſplit in the poliſhing.

The braſs, the ſilver, and the arſenic in this compoſition appear to have their diſtinct uſe; the braſs makes the mixture tougher, and ſomewhat ſoftiſh, the ſilver improves its colour, and the arſenic renders the texture remarkably finer, cloſer, and leſs porous; a larger proportion of this however would make the metal liable to tarniſh

Sir J. Newton's ſpecula were compoſed of 6 parts of copper, 2 tin, and 1 arſenic; they are upon the whole very good; but after being poliſhed exhibit a rather yellow caſt.

The other alloys of copper are not of much importance, and will be found under the reſpective metals to which they belong.

Copper, *white*, a kind of metal white as ſilver, frequently brought from China, and ſuppoſed by many to be natural. But it is only an allay of copper, zinc, and arſenic, in certain proportions. It is made with difficulty, becauſe of the volatility of the two ſemi-metals; and, as its quality is noxious, it is not much uſed.

Copper, in *Military Affairs*. No other metal is allowed in magazines, or for barrels of gun-powder.

Copper, in *Calico-Printing*, a veſſel in which the operations of dyeing, dunging, rinſing, &c. are performed, and which derives its name from the material it is generally conſtructed of. As theſe veſſels are uſed indifferently for any of the above purpoſes, their ſize, form, and arrangement, are generally the ſame, and vary little throughout the whole kingdom. They are always circular, from 4½ to 5 feet diameter at the top; 3½ to four feet deep, and about the ſame in width, acroſs the bottom, which is the thickeſt and ſtouteſt part of the veſſel. This circular form, though in general uſe, is perhaps the worſt that could have been deviſed for the purpoſe of calico-printing. It is no doubt the firſt that was employed, and has advantages in point of ſolidity of form, and eaſe of tranſportation from one place to another, over any other. For the purpoſe of dyeing, however, or any operations where goods are kept for a long time at a boiling heat, and turned over the winch, it is the moſt inconvenient that could have been adopted.

In a veſſel of this ſize and form, it is cuſtomary to dye from ſix to twelve pieces of twenty-eight yards each, at one operation. The goods are diſpoſed either in two lengths of four or ſix over the winch; or, when quick turning is neceſſary, in one length only, in which caſe, ſix pieces, or at moſt eight, are diſpoſed equally over the whole ſurface of the winch. In this latter caſe, the inconvenience of the circular form is particularly felt. It is evident that when ſix or more pieces are crowded upon a winch, thoſe which are at the extremities will have little or no ſpace in which to float, without diſturbing thoſe which are nearer the centre; whilſt, on the other hand, thoſe which are in the middle will have more than ſufficient, and will float in the copper, ſcarcely ever touching its ſides. In conſequence of this, the pieces at the extremities of the winch, being crowded, will preſs along the ſides of the copper, and thus be expoſed to greater heat and hazard of copper-marking, than thoſe which are in the middle. Their diſpoſition on the winch will alſo be deranged, and the copper-man, with all his care and attention, will be unable to preſerve that order and regularity in the diſtribution of their folds, ſo eſſentially requiſite in good dyeing. When the copper is in a ſtate of ebullition, theſe evils increaſe, and it rarely happens that the moſt experienced dyer can keep his goods diſengaged, or prevent their getting completely faſtened, when he has two lengths of ſix over the winch, and keeps them twenty or thirty minutes at an actual boil.

By adopting a ſquare, or, what is ſtill better, an oblong veſſel of the ſame capacity as the former, theſe inconveniences are in a great meaſure done away; the goods have all equal ſpace to float in, are equally removed from the centre and ſides of the veſſel, and preſerve their order and diſpoſition on the winch, even in a ſtate of ebullition, with eaſe, certainty, and comparatively trifling attention.

Dye-coppers are generally ſet up in brick work, with each their ſeparate and diſtinct fire-place, chimney, &c.

The ſame principles apply to the heating of theſe veſſels as to all other boilers, but we need not enter here upon a ſubject which will be more fully treated of in another part of this work. The recent improvements in the application of ſteam, as a vehicle of heat, are however of ſuch importance, and have at this moment excited ſuch general intereſt amongſt dyers, and calico-printers, as to claim a ſhort notice in this place.

Mr Gott, of Leeds, was the firſt who applied ſteam in the large way, to the heating of dye-coppers, and the ſucceſs of his experiment was ſo complete, as to induce many others to follow his example. This mode, which is the ſimpleſt and moſt economical that can be employed, conſiſts in throwing the ſteam directly into the dyeing veſſel. One ſteam boiler, ſituated at the extremity of the building, ſupplies his numerous coppers which are diſpoſed promiſcuouſly about the dye-houſe, unincumbered with fire-places, aſh-pits, chimneys, &c. and ſimply ſurrounded with a caſing of brick, to ſupport the copper, and confine the heat.

The ſteam is conveyed in horizontal pipes, carried along the ceiling of the dye-houſe, from which deſcend vertical tubes of from $\frac{3}{4}$ of an inch to $2\frac{1}{2}$ inches diameter, according to the ſize of the copper they belong to. Theſe ſteam tubes all paſs down on the outſide of their coppers, and enter them horizontally at the level of their bottoms; and are furniſhed with braſs cocks for regulating the admiſſion of the ſteam, or entirely interrupting it when the copper is not wanted.

The rapidity with which theſe coppers are heated, is truly aſtoniſhing. One of the largeſt in Mr. Gott's dye-houſe of 1800 gallons capacity, according to count Rumford, was brought to the boiling point in half an hour. The ſaving of fuel, though in general over-rated, is another advantage gained by this mode of applying heat. Mr. Gott ſtates this at two-thirds of the quantity conſumed when the coppers are heated by ſeparate fire-places; but this is evidently too much. The ſaving conſiſts in the application of fire to one veſſel only of large dimenſions, inſtead of to a number of ſmall ones; and though this is certainly accompliſhed with leſs expence of fuel, yet, if the fire has been well and properly applied in the latter caſe, the ſaving will amount nearer to one-third than to two.

The burning of the copper ſides and bottoms, when heated by a naked fire, is a heavy expence in a large eſtabliſhment, and often a ſource of ſerious inconvenience. By the application of ſteam, this is entirely done away, and even copper veſſels themſelves, for many operations, rendered wholly unneceſſary. Wooden veſſels have been ſubſtituted, with great advantage, in their ſtead, and when the uſe of copper cannot be diſpenſed with, it may be employed in thin ſheets, ſupported by a frame work of brick or wood. Important as theſe advantages are in an economical point of view, the ſyſtem of ſteam-heating has, if poſſible, ſtill more powerful recommendations. The eaſe, elegance, and regularity, with which the heat can be tranſmitted by a ſteam tube, are of themſelves ſufficient to entitle it to decided preference.

By the adjuſtment of the ſteam-cock, the rate of heating is ſo regulated, that the copper may be brought to the boiling point in any given time, with an exactneſs as well as celerity, unattainable by the other mode. The heat may in an inſtant be withdrawn, or rendered ſtationary at any fixed point, by a ſingle turn of the cock, the firſt of which is impracticable, and the latter extremely difficult, when the coppers are heated by ſeparate fire-places. The ſides and bottom of a dyeing copper, expoſed to a ſtrong and naked fire, are always much hotter than the dye-liquor, and occaſion copper-marks and unevenneſs in the goods, in ſome caſes difficult to avoid. This inconvenience is entirely removed by the uſe of ſteam, ſince the dyeing-veſſel deriving all its heat from the heated liquor within it, can never, it is evident, acquire a higher temperature.

The ſucceſs of Mr. Gott's experiments was ſuch, that many of his neighbours, at firſt much prejudiced againſt it, immediately adopted the plan. With a liberality worthy of imitation, his dye-houſe was open to all inquirers; and ſuch was the intereſt excited by this new and extraordinary mode of applying heat, that experiments were immediately inſtituted in different parts of the country, with a view of extending this improvement to other branches of the art of dyeing. Mr. Gott had proved and eſtabliſhed the practice as far as the dyeing of woollen goods was concerned, and little more remained to be done; in its application to calico-printing and the dyeing of lighter goods, however, difficulties occurred, of ſuch a nature, as wholly to diſcourage many whoſe trials were made in a haſty ill-concerted manner, and conſiderably to embarraſs thoſe whoſe experiments were conducted with greater ſkill and patience.

The great, and only well-founded, objection aroſe from the agitation into which the water was thrown when it approached the boiling point, by which the goods were entangled and faſtened, much more than in the ordinary mode. This inconvenience was not felt in Mr. Gott's dye-houſe, where the goods being woollen, and of much greater weight and ſubſtance, were leſs liable to be toſſed about by the aſcending currents from the ſteam-tubes than the thin and lighter goods manufactured from cotton. The evil was often increaſed by want of ſufficient attention to the regulation of the ſteam-cock; thrice the quantity of ſteam neceſſary to maintain the copper at the boiling point being admitted, which, retaining its elaſtic form at that temperature, paſſed through the copper uncondenſed, and threw the goods into the greateſt confuſion.

To diminiſh the agitation, it has been found neceſſary to break the force of the current, by introducing the ſteam in ſmall quantities, through two or three different openings, or in ſome caſes by introducing a falſe bottom, pierced full of holes, between the goods and the end of the ſteam-tube; by this means, and ſtill more by carefully admitting only the neceſſary quantity of ſteam, the agitation may be ſo far reduced, as to be no longer troubleſome.

The accumulation of condenſed water in the dye-copper, is a neceſſary conſequence of this mode of applying ſteam, and cannot be avoided. Where it is an object to diminiſh this as much as poſſible, it may be accompliſhed by uſing ſtrong, or which is the ſame thing, very hot ſteam; but it does not appear that any great inconvenience reſults from this trifling increaſe, which ceaſes when the copper has attained the boiling point, due allowance being made for it in the firſt inſtance, when the veſſel is filled with cold water.

When ſtrong ſteam is rapidly thrown into a veſſel filled

with cold water, the condenfation is inftantaneous, and attended with a loud noife, and violent fhock.

We have feen a ftone ciftern of large dimenfions, and firm joinings, nearly fhaken to pieces by the incautious admiffion of fteam, and many of the early experimenters complained that their coppers were nearly knocked to pieces, and that few would hold water after being heated once or twice.

This inconvenience may be corrected by ftopping the end of the fteam tube, and piercing the fides full of fmall holes, or, which is ftill better, by turning up the end of the pipe, and fixing a valve in it. In either cafe the fteam is emitted through the openings in ftreamlets, or fheets of fmall volume, whofe condenfation is attended with trifling noife, and little agitation of the veffel. Several dye-houfes in Lancafhire and Chefhire have been fitted up on thefe principles, and, the coppers, thus heated, are ufed, with few exceptions, for every purpofe of calico-printing.

Mr. Gott, as we have before ftated, was the firft who introduced this improvement on a large fcale, the idea of which, count Rumford informs us, was derived from the perufal of his feventh Effay. We know not what fhare the count's publication might have in deciding the trial, but the idea of heating water by fteam had occurred long before that time to Mr. Watt; and, if we miftake not, a warm bath at Soho had been heated in this way, and feen by Mr. Gott, and many others, to whom the idea of its application to more ufeful purpofes had naturally occurred.

For fome few purpofes we believe this mode of applying heat, by throwing fteam directly into the dye-copper, is lefs advantageous. When goods, for example, are kept a long time at a low heat and never boiled, the accumulation of condenfed water, in this cafe, continues to the end of the operation, and weakens confiderably the effect of the dye. All the advantages of this mode may, however, be obtained without any of the inconveniences we have before alluded to, by furrounding the dyeing-veffel with a cafing of caft iron, and throwing the fteam in between this and the copper. The heat in this cafe is tranfmitted through the fides of the copper, as in the ordinary mode of heating by a naked fire, and the condenfed water is carried off from the cafing either by a reverfed fyphon, eight or nine feet long, or, when the fituation will not admit of this, by a floating valve. In this way the noife and fhock, from the rapid condenfation of fteam in cold water, the agitation in the dye-copper, and the condenfed water, are all completely got rid of. The apparatus is, however, lefs fimple and much more expenfive than the former.

A ftrong fteam is neceffary to produce the boiling heat in a dye-copper cooled by the continued expofure of the goods on the winch, and the veffel and joints muft be found and ftrong to fupport this preffure. Both modes have their advantages, and will, we have little doubt, in a few years entirely fuperfede the ordinary mode of heating by feparate fire-places.

Copper-*mark*, is a ftain, difcolouration, and unevennefs in dyed goods, caufed by contact with the fides of a *hot* or *dirty* copper, during the operation of dyeing. In the ordinary mode of heating, as has been obferved in the foregoing article, the bottom and fides of a dyeing-veffel, when expofed to a ftrong and naked fire, are much hotter than the dye-liquor. When this is the cafe, and the colours pale and delicate, fimple contact with the hot copper is fufficient to caufe unevennefs, either by affecting the hue by the excefs of heat, or enabling the mordant to combine with an extra portion of colouring matter. This inconvenience is in general remedied by placing a bafket of wicker work within the copper, which prevents the goods from touching the fides of the veffel; it is ftill more completely guarded againft by heating the copper with fteam, in the manner already defcribed.

The fides of a copper will often occafion marks or ftains when the veffel has been negligently wafhed out, and efpecially when it has not been ufed for fome time. A dye-copper not in ufe fhould always remain filled with clean water. It prevents the formation of a ruft on its furface, which fimple wafhing will not remove, and which acts as a mordant, and fixes the dye whenever it touches the cloth.

Copying of Letters

COPYING *of* LETTERS, *and other writings.* The celebrated Dr. Franklin made feveral effays, many years ago, for fpeedily multiplying the copies of his own hand-writing, which he exhibited to M. Alexis Rochon, of the French National Inftitute, and director of the Marine Obfervatory at the port of Breft; an account of which he has given in his memoir on the Typographic Art. This method confifted in writing upon fmooth paper, with ink containing much gum, which was afterwards fanded with emery, or powder of caft-iron, and by means of a rolling-prefs, fuch as is ufed by the copper-plate printers, the ftrokes of the writing were transferred to a plate of rofe copper or pewter. This plate fupplies as many copies as the depth of the engraving can allow; but the copies are far from being beautiful, and the ground is fpotted and fpoiled. Before Dr. Franklin's procefs was communicated to M. Rochon, he fhewed him that by writing with a fteel point on a copper-plate previoufly varnifhed, a more fatisfactory refult might be obtained, by etching the ftrokes with nitric acid to a fufficient depth, for the fubfequent ufe of a liquid ink fimilar to that of the printers. In this cafe, the plate may be wiped without precaution, and twelve or more copies may be pulled off upon coarfe paper. Thefe proofs are foul and reverfed; and, therefore, in order to have them neat and in the proper direction of the writing, it becomes neceffary to place the fame number of leaves of white paper, wetted and prepared, upon the twelve proofs; and while the ink is ftill frefh, the whole being paffed together through the rolling-prefs, the fame number of leaves of counter-proofs are obtained as there were proofs; fo that inftead of twelve turns of the prefs, thirteen will be required to fupply twelve counter-proofs, very black, neat, and legible, even when the plate has not been perfectly wiped. This method is certainly not to be compared with fine engraving; but it may be ufeful in military operations, and all other cafes in which a fpeedy multiplication of copies is required. No precaution is here neceffary; whether the nitrous acid be more or lefs ftrong, or remain a longer or fhorter time upon the plate, or whether the plate be fomewhat heated to increafe the ftrength of the folvent, the procefs of the operation will never fail; provided the fteel point made ufe of to trace the characters through the varnifh, fhall lay the copper perfectly bare. It is of advantage that the nitric acid fhould bite deep, becaufe the counter-proofs are, by thefe means, much darker. The plate need not be well wiped, becaufe it is of no confequence whether the proof which is ufed to afford a counter-proof fhould be very clean, provided that it does not fpot the copy intended to be procured. The moft liquid kind of printers ink may be ufed. See ENGRAVING and STEREOTYPE.

In 1780, Mr. James Watt, of Birmingham, obtained a patent for a new method which he had invented to this purpofe; of which the following defcription is given in his fpecification: Let the letter or other writing, that is intended to be copied, be written with the ink hereinafter defcribed, or with any other writing-ink fit for the purpofe. Take a piece, or pieces, of thin paper which contains no fize, or glue, or gummy or mucilaginous matter, or which at leaft does not contain fo much fize, or other matter, as would make it fit for being written upon. Cut this paper, or papers, to the fize and fhape of the writing of which a copy is wanting; moiften or wet the fame thin paper with water, or other liquid, by means of a fpunge or brufh, or by dipping, or otherwife. Having moiftened or wet the thin paper, lay it between two thick unfized fpungy papers, or between two cloths, or other fubftances capable of abforbing the fuperfluous moifture from the thin paper; when it has been flightly preffed between fuch thick fpungy papers, or other fubftances, by the hand or otherwife, lay the faid thin paper, fo moiftened and preffed, upon or under the fide of the writing which is to be copied, and in fuch manner that the one fide of the faid moiftened paper fhall be in contact all over the fide of the faid writing, fo intended to be copied; and that to the other fide of the faid moiftened thin paper, there fhall be applied a piece of clean writing-paper, or cloth, or other fmooth uniform fubftance. Lay the faid writing intended to be copied, with the thin moiftened paper intended to receive the copy, (placed refpectively as above directed,) upon the board of a common rolling-prefs, or of that of which a defcription and drawing are hereunder written and drawn, and prefs them once, or oftener, through the rolls of the faid prefs, in the fame manner as is ufed in printing by copper-plates; or, inftead of ufing the faid or any rolling-prefs, fqueeze the faid papers, placed refpectively in the manner above defcribed, in a fcrew-prefs; or fubject them to any other preffure fufficient for the purpofe; by means of which preffure, in whatever manner applied, part of the ink of the writing intended to be copied fhall prefs from the faid writing into, upon, and through, the faid thin moiftened paper, fo that a copy of the writing, more or lefs faint, according to the quality of the ink and paper employed, fhall appear impreffed on both fides of the faid moiftened paper, *viz.* upon one of the fides in the natural or proper order and direction of the lines, as they are in the original writing, and on the other fide in the reverfe order and direction. But, in order to make the impreffion or copy of the writing more ftrong, legible, and durable, it is proper and ufeful to moiften the faid thin paper, which is to receive the copy or impreffion, with the following liquor, inftead of water or other liquid, and to proceed in all other refpects as is above directed; or to moiften the faid thin paper with the following liquor, and to dry the faid paper, and, when a copy of a writing is required to be taken, the faid paper, thus previoufly prepared and dried, ought to be moiftened with water or other liquid, and to be proceeded with in all other refpects as has been directed. The faid liquor to be ufed for moiftening the faid thin paper, or for preparing the faid paper previoufly to its being ufed, is made in the following manner: Take of diftilled vinegar two pounds weight, diffolve in it one ounce of the fedative falt of borax; then take four ounces of oyfter-fhells, calcined to whitenefs and carefully freed from their brown cruft, put them into the vinegar, fhake the mixture frequently for four-and-twenty hours, then let it ftand until it depofits its fediment; filter the clear part through unfized paper into a glafs veffel, then add to the faid mixture or folution two ounces of the beft blue Aleppo galls bruifed, and place the liquor in a warm place, fhaking it frequently for twenty-four hours; then filter the liquor again through unfized paper, and add to it, after filtration, one quart, ale meafure, of diftilled or other pure water. It muft then ftand twenty-four hours, and be filtered again if it fhews a difpofition to depofit any fediment, which it generally does. The liquor, thus compounded and prepared, is to be ufed as hath been directed.

N. B. In place of the vinegar, any other liquor impregnated with a vegetable acid may be ufed; and, in place of the galls, oak bark, or any other vegetable aftringent, or fubftance which is capable of becoming black, or deep coloured, with folutions of iron; and, in place of the oyfter-

fhells, any other pure calcareous earth may be ufed. But if the impreffions are not wanted to be very black, and the writing ink is good, water itfelf may be ufed to moiften the thin paper, as herein firft directed. It may be found neceffary to add more or lefs water, in the preparation of the above liquor to be ufed for moiftening the thin paper, or to vary the proportions of the other ingredients, according as they are more or lefs perfect or ftrong, or as the impreffion is required to be more or lefs deep coloured. The writing-ink, which the patentee ufes for letters or writings intended to be copied, is prepared as follows: Take four quarts, ale meafure, of fpring water; one pound and a half, avoirdupoife weight, of Aleppo galls; half a pound of green copperas or green vitriol; half a pound of gum-arabic; four ounces of roach-alum; pound the folid ingredients, and infufe them in the water fix weeks or two months, during which time the liquor fhould be frequently fhaken; ftrain the liquor through a linen cloth, and keep it in bottles, clofely corked, for ufe.

Plate III. *Mifcellany, fig.* 1. reprefents a front or end view of the rolling-prefs invented by Mr. Watt, and referred to in the above fpecification. A B C is one of the ends of an iron or wooden frame, which ferves to connect the two rollers. D, D, are two wooden or metalline rollers, turned extremely exact, or truly cylindrical, and which are mounted on iron axles, firmly fixed in them. E E is a double-ended lever, by means of which the roller, on whofe axle it is applied, may be forcibly turned round. F F reprefents the board of the rolling-prefs, on which the writings to be copied are to be laid. N N is a piece of cloth, or other elaftic pliable fubftance, placed next the roller, and above the writings to be copied; and the board, G, is a ftrong plank of wood, or plate of metal, ferving to connect the two end-pieces of the frame at bottom. H H reprefents the edge of a common table, to which the prefs may be faftened by the iron fcrew-cramps I, I. K is a flit, of which there is one in each end-piece of the frame; thefe flits are filled with elaftic fteel, or other metalline fprings, or with fome other elaftic fubftances which ferve to prefs the two rollers forcibly together. L is a brafs bolfter, fupported upon the fprings, and ferving to fupport the end of the axis of the under roller.

Fig. 2. reprefents a fide view of the rolling-prefs, in which A B, A B, are the two end-pieces of the frame. D, D, are the two rollers. E is the double-ended lever. G is a ftrong plank, or plate of metal, which forms the bottom of the frame. H H is the table on which the prefs ftands. I is one of the iron cramps which faften the prefs to the table; and M is a bar of iron which connects the upper part of the frame.

Fig. 3. reprefents a fcrew-prefs, which may be ufed, inftead of the rolling-prefs, in taking off impreffions from writings. A A is a double-ended lever. B B the fcrew. C a block of wood, or metal, which the fcrew acts upon, and which is attached to it. D D the frame of the prefs, made of iron or wood. E E is a moveable board, on which the writing to be copied is to be laid, with a cloth over it. F F the bottom or fole of the prefs, made of wood or metal. Be it remembered, that thefe preffes are made of different fizes, according to the fizes or largeneffes of the writings intended to be copied. Thofe now referred to are drawn from one fufficiently large to take an impreffion from a folio page of writing or poft paper, and are drawn to a fcale of one inch and a half for each foot, or one-eighth of their natural fize.

Fig. 4. reprefents one of Hawkins's patent polygraphs, for making two or more copies of any writing at once. A A B, is an upright frame, from the upper piece of which is fufpended a double parallel ruler, D D, E E; *d d, e e*, is another fimilar parallel ruler, of which *fig.* 5. is a plan, faftened to the board, F F, of the inftrument. Thefe two rulers are connected to a ftout bar, G; the vertical one, D D E E, by pivots at the end of the bar, H, *fig.* 4. going into holes in the projecting part of two pieces of brafs, *g g*, at each end of G; and the horizontal one, *d d e e*, by pivots at the ends of its correfponding bar, *b*, working in holes in another arm of the fame braffes. The pens are connected with the bar, G, by a curved brafs limb, *a*, turning on a fcrew put through the bar, G, as a centre. On the other fide of the bar is a fhort arm, *b*, in the fame piece with the limb: this is jointed at its upper end to the end of a fmall rod, *i*, the other end of which is jointed to another exactly fimilar limb, carrying the other pen. The pens are fitted into a fmall tube, called the pen-tube, having a fhoulder at its upper end. This fits tight into another tube, in the fame piece with the curved limb, and is pufhed in as far as the fhoulder of the pen-tube will allow.

The weight of the machinery is fufpended by eight fmall fpiral fprings, I, faftened to a ring fixed to the bar, G; their upper ends are connected with the end of a double jointed lever, K, which can follow the motion of the bar, G, without ftretching the fprings too much. The rod, L, by which the perpendicular motion is fufpended, turns upon pivots working in pieces of brafs beneath the piece, B: the right hand one is called a regulator, and has two fcrews, one moving the pivot vertically, and the other horizontally, for adjufting the inftrument. The two bars, *e e*, of the horizontal motion are connected with *d d* by pivots at the end of *b*, fo that *d d* can be lifted up without moving the other, whofe weight is fupported upon two fmall brafs wheels *i, i*. The frame, A A B, when the inftrument is not in ufe, turns down on the board, F F, and is kept faft by a fpring lock, which is opened by pufhing in a round button, *k*. The frame now forms the fides, and the front board becomes the lid, and, when fhut down, is locked by a lock, M. In explaining the ufe of the inftrument, we cannot do better than copy the printed directions fold with the inftrument. Choofe two goofe quills, taking care they are of the fize wanted; make them into pens, and put them into the pen-tubes. Having introduced them with the nibs firft, apply the fhoulder end of the pen-tube againft the femi-circular hollow, in the upright part of the gauge, Q, *fig.* 4. and pufh the pen through the tube, till the nib reaches a line drawn acrofs the end of the gauge; flide the pen-tube into the fixed focket, until the fhoulder of the pen-tube ftop it, holding by the fixed focket, and not by the work, fo as not to ftrain the machinery. If the polygraph is in order, the pens will now write, draw, or copy whatever may be required, with the greateft exactnefs. To prove the machine's being in order, bring the pens to the upper part of the paper, and try if they both touch; if not, with a fmall fcrew-driver turn the perpendicular fcrew of the regulator, till they touch equally. Bring the pens to the bottom of the paper, and move the horizontal fcrew till they both touch. When a pen wants mending, nothing more is neceffary than to take the pen-tube out of the focket, mend the pen, gauge it, and return it into the focket again. When the machine is out of ufe, wipe the pens clean, and place the left one, with the curved limb, on the hook beneath the horizontal rulers. Let down the frame, A A B, which faftens by a fpring-lock, and at the fame time raifes the writing-board, which then becomes the lid of the portable cafe for the polygraph.

The patent now belongs to Mr. Farthing, Cornhill, who manufactures the inftruments.

Thefe inftruments are made with three, four, and five pens, and anfwer the purpofe very well.

Cordage

CORDAGE, is uſed, in *general*, for all ſorts of ropes and cords, great and ſmall; and more particularly for thoſe that are uſed in the rigging and fitting out of ſmall veſſels. The word is alſo uſed for the art of preparing and manufacturing the ropes, &c. See CABLE. See alſo ROPE, and RIGGING.

The naval cordage of different ages and nations has been formed of very different materials. Thoſe of the earlier ages were probably thongs of hide or leather; the uſe of which was retained by the Caledonians in the third century, and by the nations north of the Baltic in the ninth and tenth centuries. They are even now uſed as ropes in the weſtern iſles of Scotland. Theſe were ſuperſeded in the ſouthern parts of Britain, and on the continent, at an early period, by iron chains. Accordingly we find, that in the maritime and commercial country of the Veneti, who were intimately connected with the Belgæ of Britain, iron chains were uſed for cables in the days of Cæſar. However, in the more improved countries of the ſouth, thongs of leather and chains of iron had long given place to the uſe of vegetable threads; and the art of combining them into ſtrong cords was underſtood and practiſed. In this manner the Greeks uſed the common ruſhes of their country, and the Carthaginians applied to the ſame purpoſe the ſpartium or broom of Spain. And as all the cordage of the Romans was formed of theſe materials, at their laſt deſcent on our iſland, the art of manufacturing them would neceſſarily be introduced with the Roman ſettlements among the Britons. Under the direction of the Roman artiſts, their *junci*, or ruſhes, would be wrought into cordage. Accordingly the remains of old cables and ropes are ſtill diſtinguiſhed among the Britiſh ſailors, by the name of "old junk." Moreover, the Roman ſails, which, in the days of Agricola, were compoſed of flax, were afterwards made of hemp; and our own are therefore denominated *cannabis*, or "canvas," by our preſent mariners. About the ſame period, the ſame materials were ſubſtituted for the junk of the Britiſh cordage; for the uſe of hempen ropes upon land, and of hempen nets for hunting, was very common among the Romans in the firſt century. The Indians ſtill make their cordage of the bark of cocoas, and other trees, and of ſhreds of plants. The cordage of the Britiſh navy is made of the Riga or beſt Peterſburg break hemp, and tarred with good Stockholm or Ruſſia tar.

The cordage is ſaid to be *baked*, when, having paſſed a ſtove, or other hot place, it is drained of all its moiſture. *White* cordage is that not yet pitched. *Cordage pitched in the ſtove*, is that which is paſſed through hot pitch as it comes out of the ſtove. Each quintal of cordage may take up about twenty pounds of pitch. The cordage is ſometimes pitched in the thread. For the method of making ropes and different ſorts of cordage, ſee ROPE-*making*.

By 25 Geo. III. c. 56. no perſon ſhall uſe, in the manufacture of any ropes for ſhipping, (or ſell the ſame,) hemp called ſheet chucking, half clean, whale line, or other topping, cordilla, damaged hemp, or any hemp from which the ſtaple part thereof ſhall have been taken away by the manufacturer, on pain of forfeiting, for the manufacturer, ſuch rope, and treble the value of it; and for the vender, not being the manufacturer, a ſum equal to treble its value. For the better diſtinguiſhing the quality of ſuch ropes, that which is inferior to clean Peterſburg hemp ſhall be deemed *inferior* cordage, and marked accordingly, by running from one end of it to the other three-tarred mark yarns, ſpun with turn contrary to that of rope yarn, and alſo one like tarred yarn in every other rope for the uſe of ſhipping; and the maker ſhall mark or write, on a tally to be affixed on it, the word "ſtaple," or "inferior," (as the caſe ſhall be,) and alſo his name, ſigned by himſelf or his attorney, together with the name of the place where manufactured; and in default thereof, ſhall forfeit 10*s*. for every hundred-weight. And if any ſuch rope-maker ſhall wilfully or knowingly permit his name to be put to any ſuch ropes, not being of his own manufacture; or if the vender or proprietor, or any other perſon, mark upon the tally the name of any perſon, not being the manufacturer, he ſhall forfeit 20*l*. And if any perſon ſhall make any cables of any old or worn ſtuff, which ſhall contain above 7 inches in compaſs, he ſhall forfeit four times its value. Foreign-made cordage, for which no duties have been paid, belonging to a ſhip owned by any of his majeſty's ſubjects, reſident in Great Britain, or the Britiſh

colonies, and entering any port in this kingdom, ſhall be duly entered on oath at the cuſtom-houſe (ſtanding and running rigging excepted); and before the ſhip be cleared inwards, the maſter ſhall pay the duties, on pain of forfeiting the cordage, and 20*s.* for every *cwt.* of it. Upon the importation of cordage, tarred or untarred, there is a duty payable of 8*s.* 6*d.* *per cwt.*, and no drawback allowed upon exportation; and in the port of London there is a farther ſcavage-rate of 1*d.* *per cwt.* of 112 *lbs.* upon the importation of cable-ropes for cordage.

As to the ſtrength of ropes, or cordage, M. Reaumur takes occaſion, in the Memoirs of the Royal Academy, to conſider the queſtion, whether a rope compoſed of ſeveral twiſts, or ſtrands, interwoven, *v. gr.* ten, have more ſtrength to ſuſtain a weight, than the ten twiſts would have ſeparately, placed parallel over one another; or, which is the ſame thing, whether, if each twiſt be capable of ſuſtaining the weight of a pound, the whole cord be able to ſuſtain more than ten?

On the one hand, 1. By virtue of the twiſting, the diameter of the rope is made larger than are thoſe of the ten twiſts together; but it is apparently by its thickneſs that a rope ſuſtains a weight, or reſiſts a fracture. 2. Twiſted ſtrands have not all, as when parallel, a vertical direction with regard to the weight: ſeveral of them, and even the greateſt part, have oblique directions, and of conſequence do not bear all the ſhare of the burden they would otherwiſe bear. In effect, they are inclined planes that are only preſſed with a part of the load.

Hence it would follow, that the ſurplus of the ſtrength of the twiſts might be employed in raiſing a larger weight.

On the other hand, it is true, that, in twiſting the ſtrands, ſome are ſtretched, and others left more looſe; and the new tenſion given the former, ſerves to weaken them, and has of itſelf the effect of a weight: thus they become leſs able to ſuſtain one ſo large. Thoſe more lax, on the contrary, evade, in ſome meaſure, the action of weight: for the action is diſtributed equally on the ten ſuppoſed equal twiſts; and if ſome, by reaſon of their particular diſpoſition, receive leſs than their quota, the weight will act more forcibly on the reſt, and will break them firſt, as being more tenſe; after which, it will eaſily diſpatch the reſt, as not being in ſufficient number to oppoſe it.

This is the ſum of what can be urged for and againſt the twiſting: to decide between them, M. Reaumur had recourſe to experiment. The reſult was, that, contrary to all expectation, he ſtill found the twiſting diminiſhed the ſtrength of the rope: whence it is eaſily inferred, that it diminiſhes it the more, as the rope is the thicker. For inaſmuch as the twiſting diminiſhes; the more twiſting, the more diminution.

The reſiſtance or friction of cordage is very conſiderable; and by all means to be conſidered in calculating the power of machines. M. Amontons obſerves, in the Memoirs of the Royal Academy, that a rope is ſo much the more difficult to bend, 1. As it is ſtiffer, and more ſtretched by the weight it draws. 2. As it is thicker; and, 3. As it is to be more bent; *i. e.* as it is to be coiled, for inſtance, into a ſmaller ring.

The ſame author has thought of ways to prove, in what proportion theſe different reſiſtances increaſe: that ariſing from the ſtiffneſs or rigidity occaſioned by the weight which draws the rope, increaſes in proportion to the weight; and that ariſing from its thickneſs, in proportion to the diameter. Laſtly, That ariſing from the ſmallneſs of the gyres, or pulleys, about which it is to be wound, is indeed greater for ſmaller circumferences than large ones, but does not increaſe ſo much as in the proportion of thoſe circumferences.

On this footing, the loſs a machine ſuſtains by the cordage, being eſtimated in pounds, becomes, as it were, a new weight, to be added to that which the machine is to raiſe. This augmentation of weight will render the cords ſtill the more ſtiff; which exceſs is to be computed as before.

Thus we ſhall have ſeveral ſums ſtill decreaſing; which are to be added together, as in the article of friction; and it will be ſurpriſing to ſee what a ſum they will amount to. See Friction.

Where ropes are uſed in a machine, all the reſiſtance reſulting from their ſtiffneſs is to be put together; and all that occaſioned by the friction; which will make ſo conſiderable an augmentation to the difficulty of the motion, that a power which to raiſe a weight of 3000 pounds, by means of a fixed and moveable pulley, needed only 1500 pounds, muſt, according to M. Amontons, have 3942 pounds, on account of the frictions, and the reſiſtance of the cordage.

Cordage, *twice-laid*, is that which is made of caſt rigging, as ſhrouds, ſtays, mooring and other cables, which, if not much worn, will make good ropes for wetting the ſides of ſhips, worming and woolding for cables, ſpun-yarn for ſeizing, worming for large ſtays, ſeizing for ſtrops of blocks, ſmall cable-laid ropes for warping ſhips, rat-lines, ſcaffolding-ropes for dock-yards, &c. When the yarn of this old ſtuff is overhauled, a little thin tar ſhould be poured on it, which will make it pliable and lie better. The yarn unfit for knotting will pick into oakum for caulking.

Cork

CORK, the exterior bark of a tree belonging to the genus of oak (QUERCUS *Suber*), which grows wild in the southern parts of Europe, particularly France, Spain, Portugal, and Tuscany. When the tree is about 15 years old, it is fit to be barked, and this can be done successively for eight years. The bark always grows up again; and its quality improves as the age of the tree increases. If care is not taken to strip the bark, it splits and peels off by itself, being pushed up by a second growth forming under that of the preceding year.

Stripping and preparing the Bark.—The bark is taken off by the Portuguese in sheets or tables, by cutting it with knives having two handles, similar to those which the tanners or skinners use at their beam, or horse, slitting it down after the circular incision is made, from top to bottom; to effect this incision they ascend the tree by a ladder to the part where the branches spring from the top; they then make a slice or slip: the filaments connecting the bark with the trunk are next cut down, or through, by a knife formed like our hay-spade, and which they use in nearly the same manner: the bark is frequently, through haste, broken off

at the root, in which case the two ends are diftinguifhed by the appellations of "cut end" and "faft end;" the firft is that which had been at the top of the tree, where the circular cut was firft made, and the fecond is that which had been next the ground.

Another mode of accomplifhing the artificial ftripping of the tree, is thus performed: feveral incifions are made from the top of the trunk to the bottom, and at each extremity of thefe incifions a circular cut is effected; by this operation the bark is cut off from communication with either the lower or higher parts of the tree; confequently it is entirely deprived of fupport; in a little time it loofens, and its feparation is completely accomplifhed by the hand; thus the progrefs of nature is expedited by very fimple means. Before the operation of barking is again performed upon the fame tree, fhould it be a young one, it ought to ftand three years; it is not however unfrequently cut within the period; when it is cut too young, it is generally preferved by the Englifh cork-cutter in his cellar till it alters from green to the colour proper for his purpofe, which is effected merely from the time he keeps it in that ftate, though after all, it is ftill much inferior to that taken when the tree has arrived at maturity.

After being detached from the tree, the Portuguefe "burn it," laying the convex fide of the bark to the fire; in this operation they are careful to cover all the blemifhes they poffibly can, holes are filled up in an infufficient manner either by the fwelling and ftraightening of the wood upon the fire, or by the artful introduction of foot and dirt. When the judgment of the burner is fufficiently exercifed in flattening the bark, and artificially repairing its defects, it is laid into the farm yard for fale, in ftacks, and bought by the merchants from thence for exportation.

Another method ufed in ftraightening the bark, is to pile it up in pits, loaded with heavy ftones, by which method it becomes flat, this is afterwards more completely effected in a damp cellar, and is called "laying the cork;" when this operation is finifhed it is dryed over a ftrong fire in what is called "a burning yard;" from negligence in this procefs it receives too much of that black colour which is fo frequently difcovered in articles made of cork: when fufficiently dryed it is ready for ftacking.

The cork is not burnt, but only charred on each furface; previous to this operation the pores of the bark are open, and its confequent fponginefs of texture would make it not only give too much way to the knife; but particularly in the cafe of "taps" and "bungs" would render it a filter, rather than a preferver, of liquids. It fhrinks with the application of moderate heat, and thereby clofes the pores, by which any filtration might be effected. If "burning" ever be ufed as a cover for defects, it is not an original defign but an accidental advantage, which is taken of a neceffary procefs; "bungs" and "taps" are always charred on both furfaces; good bottle corks, though the bark of which they are made is likewife fubjected to the operation of fire, do not after they are cut exhibit any marks of that element, being cut in the length way of the wood, the pores lie in a contrary direction, and the charring confequently is taken off by the procefs of rounding them.

The cork tree as well as the ufes to which the bark is applied, &c.—This tree, as well as its ufe, was known to both the Greeks and Romans. By the former it was called *phellus*. Theophraftus reckons it among the oaks, and fays, that it has a thick flefhy bark, which muft be ftripped off every three years to prevent it from perifhing. He adds, that it was fo light as never to fink in water, and on that account might be ufed with great advantage for a variety of purpofes. That the *fuber* of the Romans was our cork-tree is generally and juftly admitted. Pliny relates of it every thing faid by Theophraftus of the *phellus*; and from his account we learn, that at the period when he wrote, cork was applied to as many purpofes as at prefent. At that time fifhermen made floats to their nets of cork; that is, they affixed pieces of cork to the rope which formed the upper edge of the net, in order to keep it at the furface of the water. Another ufe to which cork was applied, according to Pliny, was for anchor-buoys. "Ufus ejus ancoralibus maxime navium:" that is, as this paffage may be interpreted, it was ufed for making buoys, called "Ancoralia," which were fixed to the cable, and by floating on the furface of the water, over the anchor, pointed out the place where it lay. Our navigators ufe for that purpofe a large but light block of wood, which, in order that it may float better, is often made hollow. See Buoy.

Another ufe of cork among the Romans was for being made into foles, which were put into their fhoes, in order to fecure their feet from water, efpecially in winter; and, as high heels were not then introduced, they ferved the purpofe of elevating ladies and making them appear taller than they naturally feemed. The practice of employing cork for jackets to affift in fwimming is alfo very ancient; for we are informed, that the Roman whom Camillus fent to the capitol when befieged by the Gauls, put on a light drefs, and took cork with him under it, becaufe, to avoid being taken by the enemy, it was neceffary that he fhould fwim through the Tiber. When he arrived at the river, he bound his clothes upon his head, and placing the cork under him, was fo fortunate as to fucceed in his attempt. The moft extenfive and principal ufe of cork at prefent is for ftoppers to bottles. To this purpofe it is excellently adapted; becaufe it is very light, may be eafily compreffed, and expands again by its elafticity as foon as the preffure upon it is removed, and, therefore, it fills and ftops up very clofely the fpace into which it has been driven by force. Befides, it may be eafily cut into all forms; and though it abounds with pores, which are the caufe of its lightnefs, it fuffers neither water, beer, nor any common liquid to efcape through it, and it is but flowly and after a confiderable interval that it can be penetrated even by fpirits; its numerous pores feem to be too fmall to afford a paffage to the fineft particles of water and wine, which can with greater facility ooze through more compact wood that has larger or wider pores. This ufe of corks was not altogether unknown to the Romans; for Pliny exprefsly fays, that it ferved to ftop veffels of every kind, and inftances of its being employed for that purpofe may be feen in Cato (De Re ruftica, cap. 120.) and Horace (lib. iii. od. 8. 10.); its application to this ufe does not feem, however, to have been very common as other fubftances have been generally employed for this purpofe. Stoppers of cork feem to have been firft introduced after the invention of glafs bottles, of which no mention occurs before the 15th century. See Bottles.

This wood is ftill formed into foles for fhoes, into corks and bungs for ftopping bottles, &c. into a floatage for the nets of fifhermen; it is employed generally, though perhaps with a confiderable degree of error in teaching the art of fwimming; it is alfo ingenioufly ufed on account of its lightnefs, when an amputation of the human leg has been neceffary, to fupply the deficiency; the Spaniards line ftone walls with it, which not only renders their houfes very warm but corrects the moifture of the air; the Egyptians made coffins of it, which being covered in the infide with a refinous com-

position preserved their dead bodies. It is burnt to make that light black substance called Spanish black, from its having been first made in Spain.

Cork bark has not only been applied as above, but also in the preservation of life, when endangered by shipwreck; the most conspicuous exhibition of its advantages is in the application of it in the construction of the "life boat" or "cork boat," as it was originally called. We have under the article *boat*, "*life boat*," given our readers a short account of that inestimable invention; since which we have procured a very valuable account by the principal secretary of the meeting who first advertised the reward; we have also obtained from the liberality of Mr. Greathead, and the interest of the gentleman alluded to, a plan or section of the boat, drawn by the original inventor, which will be given under the article Life *Boat*.

A cork jacket too has been revived from an old German discovery, by Mr. Dubourg; to preserve the lives of persons in danger of drowning, which is constructed as follows. Pieces of cork about three inches long, by two wide, and the usual thickness of the bark, are inclosed between two pieces of strong cloth or canvas and formed like a jacket without sleeves; the pieces of cloth are sewed together round each piece of cork, to keep them in their proper situations; the lower part of the jacket about the hips is made like the same part of women's stays, to give freedom to the thighs in swimming; it is made sufficiently large to fit a robust man, and is secured to the body by two or three strong tapes sewed far back on each side, and tied before; the strings are thus placed to enable any wearer to tighten it to his own convenience.

Cork in its action has the elasticity of a spring, and when pressed into any aperture, it exerts a force acting outwardly on all sides from the centre. It is this quality that makes it valuable in shutting out the external air from liquors, and elastic fluids; and it is fitted for this purpose in a degree proportioned to the impermeability of its pores. The elasticity of cork has also been employed for many other purposes in the arts; it forms the spring of the lifter in ordinary candlesticks, and where the frame is not heavy, it can be made into a good substitute for the pulleys and weights of the sashes of windows. See Candlestick and Window-sash.

Other vegetable productions have likewise been occasionally employed possessing qualities similar to cork. The spondias lutea, a native of South America, which flourishes in moist situations, and which is there called monbin or monbain, is sometimes brought to England, as a substitute for cork. The roots of liquorice are applied to the same use, and on this account, as well as its medicinal properties, is much cultivated in Sclavonia, and exported to different countries. The tree called myssa, which is found in North America, has also been applied to similar purposes.

Cork-*cutting*, or the *Manufacturing of Corks*. This business, though it is thought one of the most dirty, is not one of the least profitable; it is likewise easy in the acquirement. The cork, after being pressed into square pieces, as above noted in the treatment of the bark, is received by the cork-cutters, and if not sufficiently flat for their purpose, they "lay" it again over a fire in their "burning yard," turning the convex part to the flame; the heat by twisting the edges of the bark, counteracts the natural bend, and compels it to receive a flat form. During this operation, a considerable degree of attention is paid to smoothing it, and particularly again to cover its defects. It is next cut into slips, narrow or wide, according to the intended cork, bung, or tap, for such are the names of the general divisions in this business. The use of the two former is well known, the latter is used for stopping the tap-holes of barrels, as the name implies. These slips are again cut into squares, of a length proportioned to the use they are intended for. This operation is performed by one man, from whom they are handed forward to several others. A further division of corks takes place, of these different sorts according to their lengths, and are denominated "short," "short long," and "full long."

The cork-maker places himself before the table or plank, on which is fastened a board about three inches thick, four broad, and twelve long: immediately on a line with his left hand is a piece of wood, rising about four inches from the board, and fixed about the middle of it, on which the cork is laid, after being cut as above. This wood not only supports the cork, and is as a guide to the workman, but by its elevation above the board, gives room for the knife to cut a part of the cork in a smooth and circular manner, without striking on the table below. The piece is then turned to where the last cut ceased, and this is continued until the knife has gone completely round; the top and bottom are then pared level, and the cork thrown into a box or basket, with the rest of the same length. As the bark is not of the same quality throughout each piece, the corks are sorted by a boy into four kinds, "superfine," "fine," "common," and "coarse," and are sold accordingly.

The only tool employed by the cork-cutter is a knife about three inches broad in the blade, and about six inches long, very thin and sharp, and equal in breadth from the handle nearly to the end, which is finished by a gentle curve. This knife he sharpens upon the board where the guard is placed, by one whet or stroke on each side, after every cut, and now and then upon a common whet-stone.

From the foregoing review it is evident, that the art of a cork-cutter is principally to obtain a regular, round, and quick turn of the wrist, in guiding the knife so as to complete a pretty correct circle, and to make a smooth surface; it is on this account that the knife must be particularly sharp, to enable the workman to turn it with ease.

The parings of the cork are carefully kept, and sold to the dry colour makers, to be burnt into Spanish black.

It may be supposed that those who give the detail of any manufacture would be the best able to point out improvements in it, though this is not always the case; yet one improvement in the "laying" of the cork wood, appears of great importance to the writer of this. In the present mode, a great deal of time is lost in placing and removing the stones used to flatten the bark; and though the weight may be moderated or introduced by degrees, yet it cannot be done in that regular manner which appears the most likely to effect the purpose. In addition to which it may be observed, that in proportion as the weight is carelessly applied, will be the risk of breaking those pieces which most partake of the circular bend of the tree. To remedy this inconvenience, and to do away the old, gross, and cumbrous method, a screw might be used, such as that employed by the printers in pressing their work; by its operation a gradual pressure would be given, the former objections done away, and a much neater and workman-like method adopted.

Cutting the cork into stripes might also be accomplished with much greater facility; the whole breadth of the cork might be cut by one stroke, by means of semi-circular knives, like small cheese knives, set at certain distances, in a frame, which, by being affixed to a pole, with a cross-bar as a handle, might be driven through the whole breadth, in

the ſame time that a ſingle ſlip is cut by the preſent method.

Cork, *Acid of*, in *Chemiſtry*, a yellowiſh thick acid matter obtained by diſtilling four times its weight of nitrous acid from cork. This is ſoluble in water and has an auſtere bitteriſh taſte. It does not cryſtallize, but becomes conſiſtent like wax by evaporation; is ſoluble in ardent ſpirit; forms deliqueſcent ſalts with the earths and alkalis; and has as ſtrong an attraction for lime as the acid of ſugar.

Cork, *Mountain*, *Suber montanum*, or *Corium montanum*, in *Mineralogy*, a ſpecies of the muriatic genus of earths and ſtones, according to the arrangement of Kirwan (Mineral. vol. i.) Its colour is white, or reddiſh-white, or yellowiſh-grey, or iſabella, or ochre-yellow, or yellowiſh-brown. It is found either in thick compact pieces, and then called "mountain cork;" or in thin flat pieces, then called "mountain leather or paper;" or cellular, and then called "Caro montana, &c." The luſtre is 0, rarely 1, and tranſparency 0. Its fracture preſents fibres confuſedly interwoven with each other, ſometimes ſo ſubtile as to be diſtinguiſhed with difficulty, and thus they give the fracture a compact earthy appearance. Hardneſs 4; it takes an impreſſion, or yields like cork to the finger, and is ſomewhat elaſtic. Sp. gr. before it is penetrated by water, from 0.6806 to 0.9933; and after admiſſion of water, from 1.2492 to 1.3492. (Briſſon.) If perfectly dry, and ſufficiently thick, it gives a ſound when ſtruck. It feels meagre. Bergmann and Sauſſure found it fuſible, though with difficulty, by the blow-pipe. By Mr. Bergmann's analyſis it contains from 56 to 62 *per cent.* of ſilex, 22 to 26 of aërated magneſia, from 2.8 to 12.7 of argill, about 3 of calx of iron, and from 10 to 12.7 of aërated calx.

Cork-*ſcrew*, in *Mechanics*. *Fig.* 1. *Plate* XVII. *Mechanics*, is a ſimple cork-ſcrew, conſiſting of a ſcrew, A, turning in a female ſcrew attached by two ſmall rods to the collar B, which receives the neck of the bottle from which the cork is to be extracted; the two rods have a groove in them to receive the ends of a croſs piece, connected with the cork-ſcrew, and prevent its turning round with the ſcrew A.

Fig. 2. is nearly the ſame, except that the nut, B, is turned inſtead of the ſcrew.

Fig. 3. is called the *ne-plus-ultra* cork-ſcrew; it conſiſts of two cork-ſcrews A, B, one within the other; the ſcrew which enters the cork is fixed to the internal one. In uſing this inſtrument both ſcrews are ſcrewed up to their ſhoulders, and the whole is turned round together till the cork-ſcrew has penetrated the cork. The handle and the two ſcrews are then turned in the ſame direction, without permitting the frame to turn till the cork is drawn. The handle is then turned the contrary way, and the ſcrew drawn out of the cork by means of the ſmall ſcrew B.

Fig. 4. is a ſcrew of nearly the ſame kind, a rack and pinion being ſubſtituted for the ſcrew B.

A corking-machine is repreſented in *fig.* 5; in which A is a treadle to be worked by the foot; it is connected by a rod *b*, with an iron-lever D; the bottle to be corked is placed in a leathern caſe E, faſtened to a board ſliding in a groove; the cork is inſerted, and the bottle ſlid under the lever D, the foot is then placed on the treadle, and the cork forced in; the corks are firſt pinched by placing them under the lever at *d*, to make them enter eaſily.

Cornwall

CORNWALL, in *Geography*, the name of the most western county of England, is nearly insulated by water; having the British Channel on the south, and the Bristol Channel on the north; both seas seeming to meet near the point called the Land's End, at the extremity of the promontory on the west: on the east it is separated from Devonshire, by the river Tamar, and an artificial boundary of a few miles at the northern extremity. From this boundary the land continually contracts its breadth to the westward, assuming something of the appearance of a cornucopia. The widest part of the county, from Morvinstow on the north, to the Rame-Head on the south, is about forty-three miles, but, from its rapid contraction, twenty miles may be considered as a medium. From Mount's bay to St. Ives, it is not more than five and a half miles across. The length of the north-east side from Morvinstow to the Land's End, is about ninety miles. The circumference is estimated at two hundred. There is a tradition that a considerable tract of land, named the Lionefs, formerly connected with this county, and extending towards the isles of Scilly, was, at a very remote period, ingulphed by the ocean.

The original British name of Cornwall appears to have been *Cernyw*, i. e. a horn or promontory; and, is supposed, by Dr. Borlase, to have been changed, by the intercourse of the natives with Romans, into the Latin term *Cornubia*, "which it retained till the Saxons imposed the name of *Weales* on the Britons, driven by them west of the rivers Severn and Dee, calling their country in the Latin tongue, Wallia; after which, finding the Britons had retreated, not only into Wales, but into the more western extremities of the island, the Latinists changed Cornubia into *Cornwallia*; a name not only expressive of the many natural promontories of the country, but also that the inhabitants were Britons of the same nation and descent as those of Wales; and from this Cornwallia, is derived the present name Cornwall." Borlase's Antiquities of Cornwall. This portion of the kingdom was included by the Romans under their first division, Britannia Prima; but antiquaries differ as to the extent of the Roman dominion in this part of the country. It is supposed that the Romans made an actual conquest of Cornwall about the same period that Claudius subdued the southern part of the island: this opinion is strengthened by many coins, pavements, urns, and sepulchres that have been discovered in different parts of the county, chiefly within the last century; and is further confirmed by the form of various forts, encampments, and road-ways. Dr. Borlase observes, that the collective mass of evidence, in favour of the Roman domination here, is so strong, that "it cannot be contradicted." Cornwall, from its soil, appearance, and climate, is apparently one of the least inviting of the English counties. A ridge of bare and rugged hills, interspersed with bleak moors, runs through the midst of it. The roads, which are chiefly carried over the higher lands, or extensive commons, convey to the traveller a much greater idea of sterility than the produce of the country will warrant; for marks of abundant fertility are displayed in the vallies, and on the sea-shores; the use of the sea-sand and weeds collected on the beach, greatly increasing the richness of the soil. The surrounding body of water renders the air extremely moist; and the interception of the clouds, by the central high lands, occasions frequent and heavy showers: these, however, are of short duration, and may be considered as conducive to health, by dissipating the noxious vapours arising from the processes of refining the ores, and introducing the vivifying qualities wafted by the genial breezes from the ocean. The seasons are more equal than in most parts of England, being generally free from intense heat or piercing cold. Frosts seldom continue long; and the snow scarcely ever continues on the ground longer than two or three days. The sea-air is considered as injurious to vegetation, the salt particles wherewith the atmosphere is impregnated, together with the violence of the

winds, prevent the growth of trees on the coasts; and it is only in the sheltered vales that the ancient natural woods are to be found. The attempt to raise plantations, in situations exposed to the south-west and northerly blasts, was hardly ever successful till within these few years, when more promising indications have attended it; the pine-aster fir being first planted as a shelter to the more tender trees. The art of husbandry appears to have been but little practised in this county, so late as three centuries ago. "Their grounds," says Mr. Carew, "lay all in common, or only divided by stiche meale, and their bread corn very little: their labour horses were only shod before; and the people devoting themselves entirely to tin, their neighbours in Devonshire and Somersetshire hired their pastures at a rent, and stored them with the cattle they brought from their own homes, and made a profit of the Cornish, by cattle fed at their own doors. The same persons also supplied them at their markets with many hundred quarters of corn, and horse-loads of bread." Borlase, in his observations on this passage, remarks, that "the people increasing, and the mines sometimes failing, the Cornish felt the necessity of applying themselves to husbandry; and their improvements answered their expectations; for, in the latter end of the reign of Queen Elizabeth, they found themselves in a capacity not only to support themselves, but also to export a great quantity of corn to Spain and other foreign parts." The agriculture of Cornwall is, notwithstanding, still but a secondary object. The portable commodities of the county are chiefly carried on the packsaddle; and the hills and steep acclivities rendering the use of sure-footed animals necessary, the breeding of mules has been successfully attended to. Great numbers are employed in carrying the produce of the mines: the price of a good mule is frequently eighteen or twenty guineas. The common horses, though small, are hardy and well adapted to a hilly country. The vegetable soils are extremely various, but their general distinctive characters may be arranged under the heads, *black growan* or gritty, and the *shelfy* or *slaty* soil. The former abounds in the high lands, the upper stratum chiefly consisting of a light black earth, intermixed with small gravel, the detritus of *granite* or growan, and hence the soil receives its appellation. This stratum, on the tops and sides of mountains, is very shallow, and not of considerable depth even on the more level and extensive wastes: its natural produce is a thin short heath, and the dwarf, or Cornish furze. A stratum of a cubical quartz is generally found beneath, of various sizes, and from four to eight inches thick; and below this a whitish or yellowish loamy clay. By digging up the quartz, and intermixing the under stratum of clay with the growan earth on the surface, a prolific soil is produced, fit for any kind of grass. The coasts of Cornwall abound with a great variety of fish; one species of which, the *pilchard*, is taken in sufficient quantity to constitute a considerable and productive branch of commerce. See Pilchard.

"The sea," says Borlase, "is the great store-house of Cornwall, which offers not its treasures by piece-meal, nor all at once, but in succession: all in plenty in their several seasons, and in such variety, as if nature was solicitous to prevent any excess or superfluity of the same kind." In this author's "Antiquities of Cornwall," the numerous species of fish that visit this coast are particularly described. The sea-sands round Cornwall probably exceed in variety those of any other county in Great Britain; the sand of every cove being different. The sand of a particular shore, cove, or bay, has generally the same colour; and a microscope shews it to be of the same substance as the adjacent cliffs, and the strata under the sea. Clays are found in this county in great variety, and many of them are eminently useful for different purposes of manufacture. The yellow clay, in St. Kevran's parish, is esteemed but little inferior to any, for casting in silver, brass, or lead; the yellow clay from Lannant is much valued for building furnaces, as the bricks made with it are supposed to have a peculiar faculty of withstanding intense heat.

The mineralogical substances of Cornwall are far more abundant than those of any district of the same extent in the world; and the scientific inquirer finds in their beauty and variety a proportionable field for his researches. Among the rocks claiming especial notice, is granite, or, as here called, *moor-stone*, of which this county affords more than any other part of England. It forms the chain of mountains, which, commencing at Dartmoor, runs through Cornwall to the sea at the Land's End, and to the northward and southward goes into primitive schistus. Granite is an aggregate of felspar, quartz, and mica; and the varieties found here are innumerable, both in the size and colour of its component parts. Between the town of Liskeard and the river Tamar are some quarries of slate; whence the inhabitants of Plymouth are supplied with covering for their houses, and for the purpose of exportation. The free-stone is of two sorts: one composed of sand and argil, the other of sand and quartz: that of the purest quality is found in the parishes of Carantor and the Lower St. Columb, and approximates to the Portland and Bath stones. The Polrudon or Pentowan stone is likewise of a sandy nature: it lies in irregular masses of three different colours, in a shelving lode about 15 feet in width. A curious production, called the *swimming-stone*, has been discovered in a copper mine near Redruth; it is of a yellowish colour, and consists of quartz in right-lined laminæ, as thin as paper, intersecting eath other in all directions, but leaving unequal cavities between them: this cellular structure renders the stone so light, that it swims on water, whence it obtained its name. Some beautifully transparent quartz are found here, crystallized in six-sided pyramids, with a correspondent hexagonal prism. That part of the county which forms the Lizard Point is composed of serpentine and hornblende of the most beautiful kind, including every shade of green, from pea-green to black, variegated by tints of purple and scarlet. The serpentine is occasionally intersected with veins of the *steatites*, so called from the Greek word for tallow, to which it has some similarity. But this curious substance is contained in the greatest abundance in the celebrated *soap-rock*, situated between the Lizard and Mullion: it is of whitish or straw colour, with veins of green, red, and purple. When embedded in its matrix, the serpentine, it feels wet, and may be compressed with the hand; but being exposed to the air, becomes indurated, and of a soapy texture. The whole soap-rock is rented by the proprietors of the porcelain manufactory at Worcester. It is remarkable, that letters written with soap-stone (*steatites*) upon glass, though insensibly fixed, are not to be moved by washing, but always appear on being moistened with the breath. Solid asbestus is often seen adhering to the pure specimens of the steatites, and is also spread, like a thin film of enamel, on the surface of some rocks exposed to the sea. The fibrous asbestus has been discovered in St. Cleer's parish, fixed to stones of the killas kind, and sometimes running through them in a wavy line. But the most important of Cornish fossils is the *china stone*, obtained in the parish of St. Stephen, near St. Austel, and forming a principal ingredient in the Staffordshire pottery. It is a decomposed granite, the felspar of which is deprived of fusibility. Its qualities were, about 40 years ago, discovered by chance, and it has since been an article of considerable

Corpach

CORPACH, in *Geography*, a ſmall village in Argyleſhire, in Scotland, is about 2 miles nearly north from Fort-William, ſituate on the eaſtern ſhore of Loch Eil. This place cannot fail of obtaining celebrity in future, on account of the great works which are now carrying on for the weſtern entrance-baſon and locks of the great Inverneſs and Fort-William, or Caledonian, canal, intended to form a communication for large ſhips between the Eaſt and Weſt ſeas, and avoid the large and often dangerous paſſage round the north of Scotland. The laborious operation of excavating, or rather hewing and blaſting the hard rock, in which the locks at this place are to be built, was begun in July 1804; and, in December of the ſame year, the formation of two immenſe banks of earth, (nearly ſimilar to thoſe we have mentioned as conſtructing at the eaſtern entrance at CLACHNACARY) was begun to extend into Eil Loch, for ſurrounding and protecting the ſea or entrance lock, which is to be formed where the ſurface of the rocky ſtratum of this diſtrict is 20 feet under the line of high water of ordinary neap tides, but where the rock ſhelves off, ſo that no cutting will be required at the tail of the rock, from whence the depth of water in the lock gradually deepens through 4, 5, 6, 7, 8, and 13 to 16 fathoms, at the diſtance of about three quarters of a mile. There is a projecting head of rock in this place, which will form the body of a pier to protect the tide-lock. The riſe of thoſe locks, which are to be conſtructed behind Corpach houſe, will bring the bottom of the canal upon the top of the ſtratum of rock; into which the lock, connecting with the firſt or ſea-lock, will be cut 11 feet 9 inches, and the third lock will be cut 4 feet into the rock. For the ſpace of a mile and quarter from theſe locks eaſtward, the cutting of the canal is level on Corpach Moſs, in ſtrong compact ſandy gravel, under about two feet of peat-moſs. According to the report of Meſſ. T. Telford and W. Jeſſop, the principal engineers in this important concern, which was ordered to be printed by the houſe of commons on the 2d June 1806, it appears, that an engine-houſe had been built, and one of Boulton and Watt's 20 horſe ſteam-engines fitted up, for pumping the water from the foundations of the firſt and ſecond locks at Corpach; where the ſide-walls of the third lock from the entrance of the canal had been built, to the height of 12 feet above the bottom, which is rock, requiring no inverted arch upon it; the fore-bay was completed, and alſo the tail-bay, forming here, alſo, the fore-bay of the ſecond lock; for theſe ingenious engineers have adopted the plan of placing the locks on this great canal in groups, and making the head-gates of one lock act as the tail-gates of the reſt, as they do at Runcorn, on the duke of Bridgewater's canal. The mortar uſed in theſe works, is from the lime-ſtone of Linmore iſland, at the mouth of the bay of Lochyol in Argyleſhire, and is found to be an excellent water cement, after being expoſed to the tide during a winter. The bank which is to incloſe the north ſide of the ſea-lock, had been carried forwards from high water mark, a hundred and forty yards into the lock, and two rail-ways of eight hundred, and five hundred yards long, reſpectively, had been laid for conveying gravel to this ſea-lock, and to the ſecond and third locks, as well as rough quarry ſtones, for facing the outſide of the bank, as it proceeds, and defending it from the ſurf of the lock. The timbers and piles have been prepared for forming a coffer dam at the extremity and within this bank, for putting in the foundations of the ſea-lock.

The firſt aqueduct at this end of the canal at Bannavie, is finiſhed, conſiſting of two arches, 9 feet wide, 10 feet high, and 252 feet long, this being the width of the canal and its banks in this place, conſtructed of ſtone quarried near the ſpot. The locks at Corpach are building with ſtone of good quality, quarried at Faſſefern, about 2½ miles north of that place, on the eaſtern bank of Loch Eil. The ſecond aqueduct at this end of the canal, over the long river at Strone, was commencing, conſiſting of a centre arch of 25 feet diameter, and two ſide-arches 10 feet wide each; theſe laſt being paved with ſtones on edge, are intended as road-arches for communication between the different ſides of the canal, except perhaps during the height of the largeſt floods in this river. Great part of the cutting and banking for the canal between Corpach and Loch Lochy, was in hand or finiſhed, but the grand chain of eight locks between Corpach Moſs and Bannavie was not begun, or intended ſo to be, until the ſea-lock and the other two locks at Corpach are completed, ſo as to admit the ſtone veſſels to proceed thus far up the line, to diſcharge their cargoes for building theſe ſtupendous locks. See CANAL.

Cotton

Cotton, in *Commerce*, the soft and beautiful vegetable down which forms the covering or envelope of the seeds of the gossypium or cotton plant. It is the spontaneous production of three parts of the earth, and is found growing naturally in all the tropical regions of Asia, Africa, and America, whence it has been transplanted and become an object of cultivation in the southern parts of Europe.

It is brought to us from the West India islands, the Spanish, Dutch, and Portuguese settlements on the coast of South America, and the isles of Bourbon and Mauritius in the East Indies. Georgia, and the southern states of North America, also annually produce great and increasing quantities. The islands and shores of the Mediterranean have long supplied Europe, and within these few years, the privileged merchants of India have brought hither considerable quantities from Surat, Madras, and Bengal.

The cotton from these different quarters of the globe varies considerably in the colour, length, fineness, and strength of its fibre. It is the produce of several species and varieties of the gossypium, and without wholly adopting the hypothesis of Quatremere Disjouval, we may admit, that difference of climate has considerable influence on the texture and quality of the cotton.

According to the observations of that gentleman, crowned by the Academy of Sciences of Paris, the produce of the countries immediately under, or nearest the equator, is to be considered as the type of excellence, and is distinguished by its fine silky fibre, the depth and peculiarity of its colour, and the height and permanency of the plant. In proportion as we recede from the equator, says our author, these strong marked characters disappear, the fibre becomes coarse, its colour perfect white, and on the shores of the Mediterranean, we behold the lofty and flourishing tree of Hindoostan, dwindled down into a stunted annual shrub.

The exceptions to this system, from a comparison of the cotton of South America and the West Indies, with that of India and the Levant, are repelled by M. Quatremere Disjouval with some ingenuity, but his observations and reasonings are too general; and we shall presently see that this system of gradation in size, colour, and fineness, from the equator to the poles, has no existence in nature, and is disproved by the characters we shall adduce of the principal varieties of cotton at present known in commerce.

It is true, that the finest cotton we have any knowledge of, is the produce of the tropical countries, as well as the deepest coloured. The delicate and unrivalled fabrics of the East, and the genuine nankeens of India and China, afford a proof of this. Yet the cotton from which they are produced, is retained at home to supply the native manufactures of the country, and is wholly unknown in commerce. The cotton of Bengal, Madras, and Surat, such as is brought in quantities to Europe, is scarcely tinged with yellow; and Siam, famous for its nankeen, is equally so for its fine white cotton, which has long been transplanted to the West Indies. The sea-coast of Georgia, and its dependant isles, though situated in latitude 33° north, ten degrees beyond the tropic, produces cotton superior in quality to the colonies of Guiana directly under the equator, whilst the inland districts of that province, and the country south of it, down to the mouth of the Mississippi, produce a cotton of greater whiteness, and far inferior in strength and fineness.

Cotton is distinguished in commerce by its colour, the length of its fibre, and its strength and fineness.

White is in general considered as characteristic of secondary

quality. The cotton of Smyrna, Cyprus, Salonica, and all parts of the Levant, is diſtinguiſhed by its want of colour. The chief part of that from North America is alſo white, *viz.* New Orleans, Tenneſſee, and Upland Georgia.

Yellow, when not the effect of accidental wetting, or inclement ſeaſon, is indicative of greater fineneſs. The cotton of the Weſt Indies and of South America is called yellow, but the colour inclines more or leſs to cream colour. That from India has a ſlight tinge of Aurora. The fine Sea Iſland Georgia, though not properly a yellow cotton, has a faint but decided tinge, which diſtinguiſhes it from the white cotton of the ſame country.

In the following liſt are enumerated the chief, and nearly all the varieties of cotton uſed in this kingdom, with ſhort notices of their quality and value.

North American Cotton.

Sea Iſland Georgia—is the produce of the coaſt of Georgia, and the ſmall iſlands contiguous and belonging to it. It has a long and fine ſtaple, but more or leſs ſilky, ſtained or dirty, on which account no other cotton varies ſo much in price. The beſt is preferred now to every other kind, and is often ſold at very high prices to the manufacturers of lace.

Upland, or *Bowed Georgia*—is the produce of the inland diſtricts, and either from the nature of the ſoil, or defective cultivation, is much inferior to the preceding. It is a light flimſy cotton, of weak, and very unequal ſtaple, having long and ſhort fibres intermixed. It is uſed chiefly for inferior goods. It derives its name of Bowed Georgia from an inſtrument like a bow, which the planters uſe in cleaning it.

Tenneſſee—much like Bowed Georgia, but in general cleaner, and ſometimes better ſtaple.

New Orleans—this alſo reſembles Bowed Georgia, but it is generally preferred both to that and Tenneſſee. The fibre of theſe three kinds is weak, compared with that of Weſt India, or Sea Iſland, and goods manufactured from it, are unable to endure the ſame hardſhip.

South American Cotton.

Pernambuca—fine, long ſtaple; clean and pretty uniform in quality; much eſteemed; principally uſed by the hoſiers.

Maranham—rather inferior to Pernambuca; not ſo even in quality, nor ſo clean; much like good Demarara, and uſed for the ſame purpoſes.

Bahia—much like Maranham; ſometimes it has the advantage.

Rio—a very inferior cotton; very brown; much ſhell in it; uſed generally for the ſame purpoſes as low Weſt India.

Surinam—has a long ſtaple; clean; yellow; it is a fine cotton, and much uſed for making ſtockings.

Cayenne—a fine good clean ſtaple, preferable to Surinam.

Demarara—the quality of this cotton has fallen off ſince the colony has been in poſſeſſion of the Engliſh. The beſt has a fine ſilky ſtrong ſtaple, much eſteemed. The inferior ſorts are rather brown, dirty, coarſe, and much mixed.

Berbice—the quality of this has of late years fallen off. The beſt has a good ſtaple, fine, ſilky, and clean; but latterly it is brown, dirty, and mixed.

Carthagena—has a very long ſtaple, but weak; it is very ſtringy, and rather dirty.

Giron—a brown coloured cotton, fair ſtaple, and generally pretty clean.

Cumena—inferior to Giron, and not ſo clean.

Carraccas—inferior to Giron; ſtill more dirty.

Laguira—inferior to Cumena, but preferable to Carracca; not ſo dirty.

Weſt India Cotton.

Bahama—Cotton from the Bahama iſlands is of various qualities. The beſt is grown from Bourbon ſeed, but is much inferior to that kind. The ſtaple is pretty good, fine and ſilky, but it is often dirty. The inferior Bahamas are very brown and dirty. The ſtaple rather ſhort but ſtrong.

Barbadoes—is of fair middle quality, the ſtaple not very long, but generally ſilky, and pretty ſtrong; often a good deal of the ſhell of the ſeed in it, which is a great objection.

Jamaica—very little cotton grown here, and that of very inferior quality; there is the long ſtaple, which is very weak, and often very dirty, and the ſhort, which is alſo very poor and dirty.

St. Kitt's—very little grown; it is in general very brown, dirty, but of fair ſtaple.

St. Lucia—the ſame.

St. Thomas—the ſame.

St. Domingo—ſometimes very clean good cotton, and likewiſe very inferior; not much comes here.

Carriacou—rather a coarſe grain, but in general clean, fair, ſtrong ſtaple, uſed by the hoſiers to mix with fine cotton, ſuch as Pernambuca.

Grenada—a good deal like Carriacou, but not always ſo clean.

St. Vincent's—rather high-coloured; clean, good ſtaple, but not very fine; a good deal cultivated for the ſize of the iſland.

Antigua—very little grown, much like St. Kitt's.

Tortola, Montſerrat, Dominica—the ſame.

Martinique—very little comes here. It is a fair middle quality.

Guadaloupe—much the ſame, ſometimes very good cotton.

Tobago—little grown, ſometimes very fair good cotton.

Trinidad—rather ſhort ſtaple, and in general very dirty.

Eaſt India Cotton.

Bourbon—the moſt even and uniform in quality of any other. It is a fine ſilky ſtaple, and very clean. It is the moſt valuable cotton brought hither, except the beſt Sea Iſland.

Surat—has a fine, but exceedingly ſhort fibre, in general dirty, containing leaf and ſand. It is the loweſt priced cotton in the market, and uſed in the manufacture of low coarſe goods.

Bengal—much like Surat, but ſtill ſhorter ſtaple, in general cleaner, and much about the ſame value.

Madras—not much brought hither. It is moſtly from Bourbon ſeed, and ſometimes not unlike in ſtaple, but in general dirty, and contains much ſhell, which renders it leſs valuable; worth little more than Surat; ſome very good will fetch the price of Weſt India.

Turkey.

Smyrna, &c.—a ſhort moſſy kind, and rather dirty, uſed for making candlewicks; has more ſubſtance than Bowed Georgia.

The preceding obſervations are intended to give general ideas of the comparative value and qualities of the different kinds enumerated, rather than preciſe and accurate deſcriptions, which, from various cauſes, ſuch as unfavourable

feafons, exhaufted foil, defective management and culture, cannot, as may readily be fuppofed, conftantly and invariably apply.

In eftimating their commercial value, we may place them in the following order, which compared with the gradation of M. Quatremere Disjonval's fyftem, prefents a curious contraft.

Sea Ifland Georgia, Bourbon—Pernambuca—Cayenne, Bahia, Maranham, Surinam—Demarara, Berbice—Bahama, Grenada, Carriacou, Barbadoes and beft Weft India—Giron, and beft Spanifh, New Orleans, Smyrna—Jamaica, St. Kitt's, &c. &c., and inferior Weft India—Bowed Georgia, Carthagena, Carraccas, and inferior Spanifh—Madras, Bengal, Surat.

The relative value of the cotton in the firft half of this feries, is tolerably permanent, and is here pretty accurately expreffed. The varieties in the other half vary confiderably. It is deduced from the average prices of the different kinds, during a period of feveral months.

It muft be obferved, however, that the low value of Eaft India cotton from Surat, Bengal, and Madras, arifes chiefly from the exceffive fhortnefs of its fibre, which, though fine and filky, unfits it for the manufacture of a fine thread by our mode of fpinning, though we are affured the natives of Hindooftan employ it in the manufacture of their fineft muflins.

The importation of cotton into Great Britain has progreffively and rapidly increafed during the laft twenty-five years, as will appear from the following ftatements, from which fome idea may be formed of the aftonifhing and unexampled increafe and profperity of our cotton manufactures during that period.

Importation of Cotton into Great Britain.

In the year	1781	5,101,920 lbs.
	1782	11,206,810
	1783	9,546,179
	1784	11,280,238
	1785	17,992,888
	1786	19,151,867
	1787	22,600,000
From 1786 to	1790	23,443,670 per an
In the year	1799	46,000,000
	1800	56,010,732
	1802	65,850,395
	1806	75,000,000 *

* This year's importation is not given from official documents, and is not therefore to be relied on as ftrictly accurate.

London and Liverpool are the great marts for cotton, the chief part of which was for a long time imported into London, but the fituation of Liverpool, in the very heart of the cotton manufactures of the north, has rendered it the principal market in the kingdom, and great part of the cotton belonging to the merchants of London is now configned there.

The following is the number of bags, of about 300 lbs. each, imported into London and Liverpool in four different years, from which may be derived a tolerably accurate idea of the relative quantities of different kinds of cotton brought into this kingdom, and of the increafed cultivation of fome particular forts.

Importation of Cotton into London.

	1798.	1799.	1805.	1806.
Hamburgh, Tonningen, &c.	7327	11208	514	137
Lifbon	5661	17818	3020	7281
Oporto	1095	2583	1373	1095
Gibraltar and Mediterranean	2748	752	1234	218
Charleftown and South Carolina	3079	3981	2113	3911
Philadelphia, Maryland, New York, &c.	2084	5172	469	1035
New Providence	1489	1911	1712	
Savannah	1221	1514		40
Smyrna	600	1208	54	1360
Guernfey	531		162	5
Jamaica	612	5003	366	639
Montferrat, St. Kitt's	729	838	1735	2325
Bahama	405			
Grenada	2122	846	1577	2632
St. Domingo	690			
Barbadoes	1911	686	1362	792
Antigua, St. Vincent's, and Tobago,	526	381		
Demarara	2581	3540	5294	4920
Martinique and Tortola	652	802		
Dominica	783			
Surinam	72	448	5040	3758
Copenhagen and Baltic		2020	601	
Berbice		'192	2467	1458
	36918	60903	29093	31606

Importation of Cotton into Liverpool.

	1805.	1806.	1791.	1799.
America	100,148	100,142	64	13,236
Lifbon	36,739	33,646	34,500	25,362
Oporto	1958	1647		
Demarara	9495	10981		
Berbice	6715	5784		8102
Surinam	3072	1139		
Barbadoes	7995	5495		
Bahamas	1634	1980		
Dominica	775	1491		
St. Thomas	1170	1743		
Antigua	83	278		
Tortola	1221	1325		
St. Lucia	1288	1389		
St. Kitt's	260	224		
St. Vincent's	183	189	25,777	28,394
Nevis	29	72		
Grenada	200	384		
Trinidad	125	287		
Cuba	175			
Montferrat	24	10		
Jamaica	2483	4011		
Bourbon	588			
Spain	608			
Ireland	450	546	3871	1690
Tobago		5		
Teneriffe		306		
Holland			1950	
Turkey			2242	
	177,418	173,074	68,404	86,784

From these statements it appears, that in 1791, sixty four bags of cotton only were brought into the port of Liverpool from North America; 25,814 into London and Liverpool in 1799, and in 1806, upwards of one hundred thousand bags into Liverpool alone; nearly half the quantity imported into the whole kingdom of every description whatever.

The cultivation of cotton is become an object of principal concern, and is rapidly increasing in the southern states of North America. The produce of some parts of Georgia, as we have before observed, is of very superior quality; and there is every reason to believe, that in a few years, it will rival in quantity, as well as quality, the fine cottons of Brazil and Guiana.

It may not, perhaps, be irrelevant to our subject, to remark here, that the colonization of Georgia formed the subject of a memorial presented to the duke of Newcastle, then secretary of state in the reign of George I., by colonel John Purry, a native of Switzerland. In this memorial, which was afterwards published, he sets out with this postulate, that "there is a certain latitude on our globe, so happily tempered between the extremes of heat and cold, as to be more peculiarly adapted than any other for certain rich productions of the earth," amongst which he enumerates silk, cotton, indigo, &c.; and he fixes on the latitude of 33°, whether north or south, as the identical one for that peculiar character. He settled some years afterwards, with a colony of his countrymen, on the river Savannah, which parts Carolina from Georgia, where he perpetuated his name by founding the town of Purrysburg; and proved, in some degree, the truth of his system, by the introduction of those objects of cultivation, which have since become staple articles of the country.

The first importation of cotton from the East Indies took place in the year 1798. This cotton is not imported by the India company, but by the privileged merchants; and the first cargo brought by the Fame, and valued at 10,000 *l.*, cleared the enormous sum of 50,000 *l.* The cotton at that time sold at 2*s.* 2*d.* per pound, the following year it fell to 10*d.*, and is now the lowest priced cotton in the market.

The following is the amount of importations since that time.

Importation of East India Cotton.

1798	4637	Bales of about 350 lbs.
1799	19714	
1800	19820	
1801	12111	
1802	8900	
1803	10476	
1804	3546	
1805	1842	
1806	8422	

All cotton whatever is subject to a duty of 2*d.* per pound, and also of $1\frac{1}{4}$ per cent. on that amount. Calculated at the prices of that article in 1803. The amount of the duty on each particular kind is as follows,

Sea Island Georgia	-	4 per cent. ad valorem
Fine Brazil	- -	8
British West India	- -	$8\frac{1}{2}$
Foreign West India	-	10
Inferior Brazil	- -	12
Turkey	- -	12
Bowed Georgia	- -	$12\frac{1}{2}$
Spanish Cotton	-	15 to $23\frac{1}{2}$

Cotton, as a vegetable substance, approaches in its nature nearly to the ligneous matter, or woody fibre, and affords, by destructive distillation, the same products, and nearly in the same proportions as the hard and heavy woods. It is distinguished by its great affinity for earths and metallic oxydes, but more especially for alumine, and iron, on which is founded the theory and practice of calico-printing.

It is little alterable, insoluble in water, and the chief part of the weaker reagents. Nitric acid converts it into various vegetable acids. Vitriolic acid acts upon it as on ligneous fibre, both are decomposed, charcoal developed, and sulphureous acid given out. It is also distinguished by the beauty and permanency of the white which it acquires by alternate exposure to the action of alkalies and atmospheric air, or oxygenated muriatic acid.

The structure of the fibres of cotton has not been well ascertained. Lewenhoeck, by microscopical examination, found them to have two sharp sides, and it seems to be owing to this circumstance, and to their possessing some asperities like the filaments of wool, that cotton greatly irritates and inflames wounds and ulcers, if applied to them instead of lint.

COTTON, in *Ancient Geography*, a town of Asia Minor.

COTTON-*grass*, in *Botany*. See ERIOPHORUM.

COTTON *Manufacture*, in *Commerce*, one of the leading and most important branches of our national industry and commerce.

The history of its progress during the last century, affords a splendid instance of the successful application of industry and talent to a branch of manufacture, unparalleled in the annals of commerce.

Scarcely fifty years have elapsed since it was amongst the humblest of our domestic arts, and was confined chiefly to the fire side and cottage of the labouring poor of Lancashire. Its products were few, and mostly for home consumption, though some articles from Manchester were exported above a century ago. Its processes were simple, and the contrivances for accelerating labour, such as had been handed down for ages past with little alteration. The population engaged in this manufacture about the year 1750, is supposed not to have exceeded 20,000, and was little more than doubled in the succeeding twenty years.

From this state of comparative insignificance, it burst forth at once with a vigour and activity which has no parallel, and from causes which we shall state hereafter, became in the short period of thirty years, one of the most flourishing and important branches of our national industry.

For our internal consumption, it affords a variety of fabrics, suited not only to the ordinary wants and comforts, but also to the elegancies of life; and for exportation, such now is our superiority, that there is scarcely a civilized nation on the earth, that is not indebted to us for some article of this manufacture, and well authenticated accounts have been published of their having been found as articles of dress amongst the distant tribes of Tartars.

In the following article we shall endeavour to trace the progress of this manufacture from its origin down to the present time, and the causes which have contributed so powerfully to raise it in a few years to a state of importance, little short of that which the great staple manufacture of this country, that of wool, has acquired during the five last centuries.

The period of its first introduction into this country is not clearly ascertained, and there are few authentic documents of earlier date than the middle of the seventeenth

century, before which time, it is probable that the manufacture of cotton was too inconsiderable to deserve much notice.

The first historical notice we meet with is in the Itinerary of Leland, who visited Lancashire in the reign of Henry VIII. "Bolton-upon-Moore market," says he, "standith most by *cottons*, divers villages in the moores about Bolton do make cottons." From this an inference has been drawn in favour of the existence of the manufacture of cotton in Lancashire at this early period, a supposition which is however completely overturned by an act passed the 5th and 6th of Edward VI. 1552; entitled "for the true making of *woollen* cloth," in which it is ordered "that all the cottons, called Manchester, Lancashire, and Cheshire cottons, full wrought to the sale, shall be in length twenty-two yards, and contain in breadth three quarters of a yard in the water, and shall weigh *thirty pounds* in the piece at least. Also that all other cloths called Manchester rugs, otherwise named Manchester frizes, full wrought for sale, shall contain in length 36 yards, and in breadth three quarters of a yard, coming out of the water, and shall not be stretched on the tenter, or otherwise, above a nail of a yard in breadth, and being so fully wrought and well dried, shall weigh every piece 48 lbs. at the least." However paradoxical it may appear, it is nevertheless clear from this passage of the act, that the Manchester cottons of that day were a species of woollen cloth, and that of the coarsest and strongest kind, as is sufficiently proved by the weight required by the statute. The testimony of Camden also to this point is decisive: when speaking of Manchester in 1590, he says, "this town excels the towns immediately around it in handsomeness, populousness, *woollen manufacture*, market place, church and college, but did much more excel them in the last age, as well by the glory of its *woollen* cloths, which they call Manchester *cottons*, as by the privilege of sanctuary, which the authority of parliament under Henry VIII. transferred to Chester."

The manufacture of these cottons was known also in Wales, as appears from the 8th of Elizabeth, 1566; in which we have the following historical fact. "In the town of Shrewsbury there hath been, time out of mind of man, and yet is, a company, fraternity, or guild, of the art and mystery of drapers, which said fraternity hath by reason of a certain trade and occupation, of buying and selling of Welsh cloth and linen, commonly called *Welsh cottons*, frizes and plains, which they have had and used amongst them, been able not only to live thereby, but also have, at their common cost, provided houses and other necessaries for poor people within the said town of Shrewsbury." The distinction of the Welsh cottons here into frizes and plains, is another proof of their being made of wool.

It is certainly singular, that the term cotton should be applied to goods manufactured wholly of wool, and which from their weight and substance could not possibly be intended as imitations of, or substitutes for, the cotton goods of any other country.

The fact is however sufficiently evident from the preceding quotations, and still further from the consideration that at the present day the *Kendal cottons*, a manufacture which has subsisted now near five centuries, are made entirely of wool, and that of the coarsest kind.

Like the Welsh cottons they are manufactured both frized and plain; and are used chiefly for negro cloathing in America and the West Indies, though some are worn at home by the poor or labouring husbandmen. Various conjectures have been offered respecting the origin of the name, but the most probable is, that it is a corruption of the word *coating*. However this may be, it is very certain that the Manchester, Cheshire, and Welsh cottons, which in all probability were derived from those of Kendal, were made entirely of wool, and that it is to these goods the observation of Leland applies in the quotation we have before given.

To whatever purpose cotton was applied, it is certain that long before we have any mention of the manufacture the raw material was imported into this kingdom. The earliest record we have met with, in a hasty and not very extensive search, is preserved by the accurate and indefatigable Hackluyt in the first volume of his Collection of Voyages, and is contained in a little work entitled the "Process of English Policy." The intent of the whole poem (for such it is) is to inculcate the absolute necessity to our commerce and existence as a free state, of England keeping the dominion of the seas; but it is chiefly valuable for the list which it contains of the different natural productions, as well as manufactures, which were at that time the objects of commercial intercourse between the European states. After enumerating the various articles which constitute the trade of Spain, Flanders, Portugal, Britain, Scotland, Ireland, Prussia, Germany, Venice, Florence, Brabant, Holland, &c., he tells us, that "Genoa resorts to England in her huge ships, named Carracks, bringing many commodities, as cloth of gold, silk, paper, much woad, wool, oil, cotton, roach alum, and gold coin; and they bring back from us wool and woollen cloth made with our own wool." It is evident from the preceding quotation, that at least as early as 1430, about which time this little work was first printed, and probably also much earlier, this country was supplied by the Genoese with cotton from the Levant. The Genoese possessed this trade till the year 1511, when, according to Hackluyt, from that time to 1534, "divers tall ships of London and Bristol had an unusual trade to Sicily, Candia, and Chios, and sometimes to Cyprus and to Tripoli, and Baruth in Syria. They exported thither sundry sorts of woollen cloths, calf-skins, &c., and imported from thence silks, camblets, rhubarb, malmsey, muscadel, and other wines, oils, cotton-wool, Turkey carpets, galls, and India spices. The Levant trade was soon after engrossed by the merchants of Antwerp, and till 1575 entirely abandoned by the English. Wheeler, who wrote in 1601, says, that "a little before the troubles in the Low Countries, the Antwerpians were become the greatest dealers to Italy, in English and other foreign merchandize, and also to Alexandria, Cyprus, and Tripoli in Syria, beating the Italians, English, and Germans entirely out of the trade, as they also soon did the Germans at the fairs and marts of their own country." Accordingly we find from the same author, that cotton was one of the many articles with which they supplied this country at that period, which they brought chiefly from Sicily and the Levant, and sometimes from Lisbon, along with many other precious articles which the Portuguese derived at that time from India. After the sacking of Antwerp the English trade to the Levant revived, and in 1621 was in a flourishing state, as appears from the testimony of Mr. Munn, in his treatise on the trade of India, in which cotton is enumerated as one of the many articles brought by our merchants from the Mediterranean.

From these quotations it is evident, that previous to the discovery of America and the West Indies, and for some time afterwards, this country, and probably all Europe, was supplied with cotton from the Levant.

How far, from this early importation of the raw material, we have a right to infer the existence of a cotton manufacture in this kingdom, may perhaps admit of some dispute,

yet it is certainly very probable that, acquainted as we muſt have been in ſome degree with the cotton cloths of the Eaſt, and other countries, and furniſhed with the material for their fabrication, ſome attempts would be made to imitate them. One great uſe of cotton no doubt, at theſe early periods, was for candlewicks; and to whatever purpoſe elſe it was applied, the manufacture had made no great progreſs in this country till the beginning of the ſeventeenth century, nor does it appear that on the continent, from whence, till within theſe few years, almoſt all our manufactures of cloth have been derived, the manufacture of cotton had made any progreſs before the middle of the ſixteenth century.

Fuſtians were firſt made in Flanders, if we may credit Guicciardini, in his hiſtory of the Netherlands, who however aſſigns no date to their firſt introduction. In the little work we have before alluded to, anno 1430, preſerved in "Hackluyt's Collection of Voyages," they are mentioned not only as an article of export from Flanders to Spain, but of import alſo from the Eaſterlings, Pruſſia, and Germany. We are diſpoſed to believe they were firſt manufactured in Italy, where, from its proximity to the countries affording cotton, as well as its earlier communication with thoſe nations which ſupplied Europe with cotton cloths, it was more likely to originate, than in the more remote and northern ſtates of the continent: and we learn alſo from Guicciardini, in another part of his work, that in 1560, Antwerp annually imported from Milan "great quantities of gold and ſilver thread, various wrought ſilks, gold ſtuffs, fuſtians and dimities of many fine ſorts, ſcarlets, tammies, and other fine and curious draperies."

That the manufacture of fuſtian came originally to this country from the Netherlands is highly probable, and it is ſaid to have been eſtabliſhed in the towns of Bolton and Mancheſter by Proteſtant refugees. Fuſtians were manufactured there in the beginning of the ſeventeenth century, and it is probable their firſt introduction was not much earlier. Had the Flemiſh carried this manufacture to any great extent, it would have found its way to this country much earlier, from the vaſt number of weavers and manufacturers of every deſcription that emigrated to England, from the time of Edw. III. down to the troubles in the Low Countries during the reign of Philip II. of Spain.

In one of the ſumptuary laws of James I., paſſed in the parliament of Scotland in 1621, it is enacted, "that ſervants ſhall have no ſilk on their cloaths, except buttons and garters, and ſhall wear only cloth, fuſtians, and canvas of Scotch manufacture." This prohibition would ſeem to imply a very advanced ſtate of the manufacture of theſe articles in Scotland.

The firſt authentic document concerning the cotton manufacture of this kingdom, is contained in Lewis Roberts "Treaſure of Traffic," publiſhed in the year 1641, and is as follows. "The town of Mancheſter buys the linen yarn of the Iriſh in great quantity, and weaving it, returns the ſame again in linen into Ireland to ſell. Neither does her induſtry reſt here, for they buy cotton wool in London that comes from Cyprus and Smyrna, and work the ſame into fuſtians, vermilions, and dimities, which they return to London, where they are ſold, and from thence, not ſeldom, are ſent into ſuch foreign parts where the firſt materials may be more eaſily had for that manufacture."

The manufacture of linen cloth, properly ſo called, never we believe, conſtituted any great part of the trade of Mancheſter, but the fuſtians, and indeed all the cotton goods of that period, were made of linen warp, compoſed of Hamburgh or Iriſh yarn, but chiefly of the latter, and theſe probably formed great part of the linen goods which Mr. Roberts ſays were returned to Ireland.

Soon after this period, fuſtians were manufactured in quantities at Bolton, Leigh, and the places adjacent; but Bolton was the principal market for them where they were bought in the grey by the Mancheſter dealers, who finiſhed and ſold them in the country. The Mancheſter traders went regularly on market days to buy fuſtians of the weavers, each weaver then procuring his own yarn and cotton as he could, which ſubjected the trade to great inconvenience. To remedy this, the chapmen themſelves furniſhed warps and cotton to the weavers, and employed perſons in all the little villages and places adjacent, to deliver out materials, and receive back the manufactured goods when finiſhed. Each weaver's cottage formed at that time a ſeparate and independent little factory, in which the raw material was prepared, carded, and ſpun, by the female part of the family, and ſupplied woof, or weft, for the goods which were wove by the father and his ſons.

The kinds of fuſtian then made were herring-bones, pillows for pockets and outſide wear, ſtrong cotton ribs and barragon, broad-raced linen thickſets and tufts, with whitened diaper, ſtriped dimities and jeans. Theſe were ſucceeded by cotton thickſets, goods figured in the loom, draw boys, and at later periods by cotton velvets, quiltings, counterpanes, corded dimities, velvets, velvetteens, and ſtrong and fancy cords. It is ſcarcely poſſible to convey any adequate idea of the varieties of cotton goods that have iſſued from the loom, ſince the firſt dawn of this manufacture to the preſent time. The pattern cards of Mancheſter goods ſent out to the continent by the leading houſes engaged in the foreign trade, have preſented ſpecimens of near two thouſand different kinds, varying in ſtrength and fineneſs, from the coarſe and heavy fabrics to the fineſt and moſt delicate muſlins, and in colour from the richeſt chintz to plain and ſelf-coloured grounds; ſome figured in the loom, ſome checked and others plain, yet all, or the greateſt part of them, compoſed entirely of cotton.

For the introduction or improvement of many of theſe branches, this country is indebted to the late Mr. Wilſon of Ainſworth, near Mancheſter, originally a manufacturer of fuſtian. He early engaged in the manufacture of cotton velvets, which, by unwearied efforts, he brought to the utmoſt degree of perfection, and conſiderably improved the mode of dreſſing, finiſhing, and more particularly of dyeing, which at that time was very imperfect. His goods, eſpecially his velvets, were finiſhed in a ſtyle that acquired a high character, both at home, and in the foreign market, and were readily diſtinguiſhed from thoſe of any other manufacturer. He cleared off the looſe and uneven fibres with razors, and burnt or ſinged them with ſpirits of wine. This mode was ſucceeded by the uſe of hot irons, in form ſomewhat reſembling the weavers' drying iron, but rounder, which were firſt employed by Mr. Witlow: and at a later period by cylinders of caſt iron heated to redneſs, over which the goods were evenly and rapidly drawn, and thus freed from that ſuperfluous down, or pile, which they had acquired in the loom, or in the various operations of waſhing, bleaching, or dyeing.

Towards the middle of the laſt century, or ſoon afterwards, the manufactures above enumerated, or ſuch of them as were then known, had become of great importance to the towns of Mancheſter and Bolton, affording various articles for home conſumption, as well as for an increaſing foreign trade, and giving employment to great part of the population of the ſurrounding country. They had arrived at that ſtate at which a pauſe muſt naturally have enſued, and

beyond which they must have advanced with the slow and gradual increase of population; which, aided by every advantage, as well as by emigation from other districts, could never have kept pace with the demand, without the introduction of those improvements to which this country owes the prosperous and unrivalled state of its cotton manufactures, and of which we shall now proceed to give some account.

The mode of spinning in use in this country at that period was by the hand; on the well known domestic machine called a *one-thread wheel*. A single spindle put in motion by a wheel and band turned by the right hand, whilst the thread was managed by the left, composed the whole of this simple apparatus, on which one person could with difficulty produce a pound of thread, by close and diligent application, the whole day. The goods then manufactured were strong and coarse, compared with those of the present day, and little or no thread finer than from 16 to 20 hanks in the pound, each hank measuring 840 yards, was then spun. It was subject, as may readily be conceived, to great inequalities, its evenness depending greatly on the delicacy of touch, which the spinner by long habit had acquired, and varied with every little difference in the extension of the thread during twisting, and the revolution of the spindle in portions of the same length. As the demand for cotton goods increased, various contrivances were thought of for expediting this part of the manufacture. A patent was obtained by a person named Paul, and some others of London, for an engine for a more easy and expeditious mode of spinning cotton, and several other attempts were made at subsequent periods, but all with equal want of success, till the invention of the Jenney, by James Hargreaves, in the year 1767. Hargreaves was a weaver at Stanhill, near Church, a few miles distant from Blackburn, in Lancashire. He was a plain, industrious, but illiterate man, and possessed little mechanical skill or talent. He resided near the print ground, the first and infant establishment of the late Robert Peel, esq. from whose hints and conversation he derived much important assistance, and whose strong and active mind was at that time engaged in the promotion of every useful improvement connected with that branch of manufacture, in which he was afterwards so extensively concerned. An anecdote is still recorded in the neighbourhood, which ascribes to accident the parent of so many useful discoveries, the first invention of the Jenney. A number of young people were one day assembled at play in Hargreaves' house, during the hour generally allotted to dinner, and the wheel at which he or some of his family were spinning, was by accident overturned. The thread still remained in the hand of the spinner, and as the arms and periphery of the wheel were prevented by the framing from any contact with the floor, the velocity it had acquired still gave motion to the spindle, which continued to revolve as before. Hargreaves surveyed this with mingled curiosity and attention. He expressed his surprize in exclamations which are still remembered, and continued again and again to turn round the wheel as it lay on the floor, with an interest which was at that time mistaken for mere indolence. He had before attempted to spin with two or three spindles affixed to the ordinary wheel, holding the several threads between the fingers of his left hand, but the horizontal position of the spindles rendered this attempt ineffectual; it is not therefore improbable, that he derived from the circumstance above-mentioned the first idea of that machine which paved the way for subsequent improvement. It consisted at first of only 8 spindles, turned by bands from an horizontal wheel, in the centre of which was fixed a vertical shaft, with a handle at the top for the spinner. The threads passed between two horizontal pieces of wood, the breadth of the machine, which, when pressed together, clasped fast the roving like the finger and thumb of the spinner, and were thus extended or drawn out. He had great difficulty in putting up the thread, or winding it on the spindle after twisting, which he at last accomplished by means of a treadle connected with a wire, and worked by the foot of the spinner. The Jenney in its original form was a rude machine. The first was made almost wholly with a pocket knife; and the clasp, by which the thread was drawn out, was the stalk of a briar split in two. It was, as may readily be conceived, defective in the construction of those parts essential to the performance of its work, and which an ordinary mechanic would have had no difficulty in contriving; but Hargreaves was obliged to work in secret, and possessing little mechanical skill, to avail himself of such assistance as he could procure, without making public the object he had in view.

Popular prejudice was soon excited against him, and the threats of his neighbours obliged him to conceal his machine for some time after it supplied the woof or weft for his own looms. It was, however, generally known that he had made a spinning machine, and his wife, or some of his family, having imprudently boasted of having spun a pound of cotton during a short absence from the sick bed of a neighbouring friend, the minds of the ignorant and misguided multitude became alarmed, and they shortly after broke into his house, destroyed his machine, and also part of his furniture. Hargreaves soon after removed to Nottingham, whither he was invited by the stocking weavers of that place, and where he assisted in the erection and management of a mill, about the time that Mr. Arkwright first settled there, after being in the same manner driven out, or rather deterred from settling in Lancashire, by the clamour and prejudice of the people. Hargreaves was little qualified, either by education or address, for the sphere of life into which he was removed, and after having assisted various persons in the construction of machinery, and communicated to each by turns the whole of what he knew, he died in poverty, ill requited by his employers, and little known to the country, which has since reaped such important benefits from his discovery. Before he quitted Lancashire, he had made one or two wheels of 12 or 16 spindles each for some of his relations or friends, and as the popular clamour abated, the number of these increased, till a second mob scoured the whole country and destroyed every machine, they could meet with. The value of this improvement however was so strongly felt, and the measures adopted against the ringleaders of this outrage so vigorous and decisive, that new wheels were immediately constructed, and it was remarked that many of those concerned in opposing their first introduction, were amongst the foremost to avail themselves of the advantages they now promised. Various alterations were made in the original machine, which from its form was inconvenient and tiresome to grown up persons, though girls of twelve or fourteen managed it with ease. The vertical wheel was substituted for the horizontal one, which rendered it much easier to work, and the treadle, which required an aukward and constrained posture, was rendered unnecessary by a simple contrivance managed by the hand. They were enlarged in their dimensions from twelve to twenty, and afterwards to thirty, fifty, and even eighty spindles, and their use rapidly extended over all the country, though their first introduction every where met with the most determined opposition. Even at Nottingham, if our information be correct, a serious affray took place on the first erection of the new machines, in which Hargreaves himself was severely wounded, and a young woman, who had accompanied him from Lan-

cashire, and had been accustomed to the management of his first Jenney, nearly lost her life.

To Hargreaves also is ascribed an improvement in the mode of carding, which, before his time, had been performed with hand cards, on the knee, a tedious and laborious operation. These were succeeded by stock cards, in which the lower card was fixed immovable on a stool or stock, which left both hands at liberty to manage the upper one. These were first used in the woollen manufacture, and introduced into Hargreaves' neighbourhood from Rosendale. His improvement consisted in applying two or three cards to the same stock, and suspending the upper cards, which from their weight and size would otherwise have been unmanageable, from the ceiling of the room by a cord passed over a pulley, to the other end of which was affixed a weight or counterpoise. With these, one woman could perform twice as much work, and with greater ease than she could do before in the common way.

The stock cards were succeeded soon after by cylinder cards, the invention of which is claimed by so many different persons, that it is impossible now to determine to whom the merit is due. Amongst the first who employed them, was the late Mr. Peel, who constructed a carding engine with cylinders at Blackburn, as early as the year 1762, in which he was assisted by Hargreaves.

Mr. Peel's engine consisted of two or three cylinders, covered with cards, but had no contrivance for stripping, or taking off the carded cotton. This was performed by two women with hand cards, who alternately applied them to the last, or finishing cylinder, and thus took off the carding by turns. This was, in all probability, the first carding machine that was made; but Mr. Peel's other avocations not permitting him to pursue the subject at that time, it was laid aside, and some years elapsed before it was improved and perfected by other hands.

Notwithstanding the severe punishment of the ringleaders of the last outrage, and the friendly means adopted to convince the labouring class of the folly and injustice of opposing these improvements, by which not only the country, but themselves, would in the end be so materially benefitted, considerable alarm and uneasiness were again excited, and though no scarcity of work had been experienced, a belief universally prevailed, that all manual labour would soon be annihilated by the use of these new machines. A third and more numerous mob therefore assembled in the year 1779, by which all the machinery turned by water or horses, both for carding and spinning, and all the Jennies above a certain size, that could be found within eight or ten miles of Blackburn, were completely destroyed. Jennies of twenty spindles, or under, were alone respected, every machine turned by water was demolished, and the large Jennies were either cut into two small ones that came within the size prescribed, or if the owner chose, into one of twenty spindles, by sawing off the extra number which was often consigned to the flames. These and similar disturbances in different parts of the country impeded for an instant, but could not arrest the progress of this manufacture. Mr. Peel, whose machinery at Altham was totally destroyed and thrown into the river, and whose personal safety was oftentimes in danger from the fury of a licentious and ungovernable mob, retired in disgust from the country, and established a cotton mill at Burton in Staffordshire, on the banks of the Trent, where he continued to reside many years afterwards.

Soon after the invention of the Jenney in 1767, sir Richard, at that time Mr. Arkwright, brought forward his improvement in spinning, on which he had been long and laboriously engaged. This distinguished character, whose perseverance and invention raised him from one of the most humble occupations in society to affluence and honour, was the youngest of thirteen children, and was born in the year 1732, at Preston, in Lancashire. In this neighbourhood was then carried on a considerable manufacture of linen goods, and linen and cotton mixed, the various operations of which he had an opportunity of becoming intimately acquainted with, and being a man of uncommon natural powers, he directed his thoughts to the improvement of the mode of spinning, which had probably been conducted for ages by the same process. The first hint for effecting this improvement, he accidentally received from seeing a red-hot iron bar elongated, by being passed through iron rollers. Between this operation and that of elongating a thread, as now practised in spinning, there is no mechanical analogy; yet this hint being pursued, has produced an invention, which, in its consequences, has been a source of national and individual wealth unparalleled in the annals of the world.

The difficulties which Mr. Arkwright experienced before he could bring his machine into use, even after its construction was sufficiently perfect to demonstrate its value, would perhaps for ever have retarded its completion, if his genius and application had been less ardent.

His circumstances were by far too unfavourable to enable him to commence business on his own account, and few were willing to risk the loss of capital on a new establishment.

Having at length, however, had the good fortune to secure the co-operation of some persons who saw the merit of the invention, and were willing to assist his endeavours, he obtained his first patent for spinning by *means of rollers* in the year 1769, and to avoid the inconvenience of establishing a manufacture of this kind in the heart of the cotton manufacture, such as it then existed, he removed to Nottingham. Here, in conjunction with his partners, he erected his first mill, which was worked by horses, but this mode of procedure was found to be too expensive, and another mill on a larger scale was erected at Cromford in Derbyshire in the year 1771, the machinery of which was put in motion by water.

This patent right was contested about the year 1772, on the ground that he was not the original inventor. He obtained a verdict however, and enjoyed the patent without further interruption to the end of the term for which it was granted.

As the essential part of Mr. Arkwright's machine was entirely new, and was applied with the happiest success in various other forms for *preparing* the raw material for spinning, of which we shall speak hereafter, we shall pause a while in the historical detail of these inventions, and explain the general principles of its construction, and the mode in which its operation was performed. Previous to the year 1767, as we have already observed, all the spinning was performed on the domestic one-thread wheel, of which there were two kinds. The first, which we have before described, required the raw material to be previously prepared and carded, and was used for wool and cotton. The cardings were soft and loose rolls of the thickness of a candle, and from eight to twelve inches long, possessing little strength or tenacity, the slightest force being sufficient to break or pull them asunder. One end of this roll being held between the finger and thumb of the spinner, and the other twisted round the point of the spindle, was rapidly drawn out during its revolution, and formed a coarse soft thread called a *roving*. For coarse woollen goods, this operation was suf-

ficient, and the thread was ready for the loom, but for fine cloth, and more especially for cotton, this operation of *twisting* and *drawing* was repeated, and the roving was converted into a smaller, firmer, and longer thread. To this last operation, the term *spinning* was more particularly applied, the first being considered as preparatory, and was generally denominated *roving*. For some time after the introduction of the Jenney, this mode of roving on the single spindle continued in use, the joining of the short rolls or cardings, rendering manual dexterity absolutely necessary.

The second mode of spinning was on the flax wheel, and used for those substances, whose fibres from their nature, but more particularly from their length, would not admit of the preparatory process of carding. Their fibres were dressed and disposed in an even and parallel direction, by an operation resembling *combing*, and were then coiled round the head of the distaff, affixed to a wheel furnished with a spindle, bobbin, and fly. The fly and spindle moved together, and were kept in rapid motion by a wheel and band, worked by the foot of the spinner. The bobbin which received the thread, ran loose upon the spindle, and moved only by the friction of its ends, in proportion as the fibres of the flax were disengaged from the distaff, by the finger and thumb of the spinner, and were twisted by the fly. If we suppose the machine itself to be left at liberty, and turned without the assistance of the spinner, the twisted thread being drawn inwards by the bobbin, would naturally gather more of the material, and form an irregular thread, thicker and thicker, till at length the difficulty of drawing out so large a portion of the material as had acquired the twist, would become greater than that of snapping the thread, which would accordingly break. It is the business of the spinner to prevent this, by holding the material between the finger and thumb, and by separating the hand during the act of pinching, that the intermediate part may be drawn out to the requisite degree of fineness previous to the twist.

To accomplish these ends by machinery, the object of Mr. Arkwright's invention, two conditions became indispensably necessary. 1st. That the raw material should be so prepared as to require none of that intellectual skill, which is capable of separating the knotty or entangled parts as they offer themselves. And 2dly. That it should be regularly *drawn out* by certain parts resembling the finger and thumb of the spinner. The first of these was completely fulfilled by the various machines and contrivances for the preparation of cotton for spinning, which sir Richard afterwards invented and obtained a patent for; the second was accomplished in his first and capital machine, since called the Twist, or Water Frame.

The contrivance for *drawing out* the thread constituted the great merit of the invention, the fly, bobbin, and spindle connected with it, being derived with little alteration from the flax wheel before described. It consisted of a pair of cylinders, slowly revolving in contact with each other, at a little distance from a second pair revolving with greater velocity, the lower cylinder of each set being furrowed, or fluted, in the direction of its length, and the upper ones neatly covered with leather to enable them to hold the thread. If we suppose the end of a roving, or loosely twisted thread, to be passed through the first pair only, it may readily be imagined that it will be gradually drawn off the bobbin, and pass through the cylinders without suffering any other sensible change in its form or texture, than a slight compression from the weight of the incumbent cylinder. But if from the first pair it be suffered to pass immediately to the second, whose surfaces revolve much quicker, it is evident that the quicker revolution of the second pair, will *draw out* the cotton, rendering it thinner and longer, when it comes to be delivered at the other side. This is precisely the operation which the spinner performs with his finger and thumb, and the application of this simple and beautiful contrivance to the spindle and fly of the common flax wheel produced that machine for which Mr. Arkwright's first patent was obtained, and which laid the foundation of all his subsequent discoveries.

Soon after the erection of his mill at Cromford, Mr. Arkwright made many improvements in the mode of preparing the cotton for spinning, and invented a variety of ingenious machines for effecting this purpose in the most correct and expeditious manner; for all of which he obtained a patent in the year 1775.

The validity of this second patent was tried in the court of King's Bench, in the year 1781, and a verdict was given against him on the ground of the insufficiency of the specification, but on the 17th of February 1785, in the court of Common Pleas, before lord Loughborough, the question was again tried, and he obtained a verdict, having established by evidence the sufficiency of the specification.

This verdict, in consequence of great numbers having engaged in the erection of machines during the interval of four years that had elapsed since the former decision, occasioned considerable alarm, and raised up a host of enemies, from whom a premium on each spindle was demanded, under the threat of immediate suit. An association was formed of the manufacturers principally concerned in the business, and another cause instituted by writ of *scire facias*, was tried before judge Buller in the court of King's Bench, on the 15th of June 1785, in which, after a very long trial, he was cast on the ground of his not being the original inventor.

Conscious that this was not the case, he moved in the court of King's Bench, on the 10th of November 1785, for a new trial; stating that, not being aware of the nature of the evidence to be brought forward on this trial for the first time after so many years had elapsed, he was then unprepared, but was now able to substantiate by proofs the falsity of great part of the evidence which went to that point. The rule however was refused, and on the 14th November 1785, the court of King's Bench gave judgment to cancel the letters patent.

The inventions claimed by Mr. Arkwright, which gave rise to these reiterated contests with the rival manufacturers of Lancashire, related chiefly to the operation of carding, which was now brought to great perfection. Before we enter however into any account of these improvements, it will be necessary to take a short view of the nature of this operation, and the mode in which it was performed at the date of Mr. Arkwright's second patent.

The *card* is a kind of brush made with wires instead of hair, stuck through a sheet of leather; the wires not being perpendicular to the plane, but all inclined one way in a certain angle.

From this description, such as are totally unacquainted with the subject, may conceive that cotton, being stuck upon one of these cards or brushes, may be scraped with another card in such a direction, that the inclination of the wires may tend to throw the cotton *inwards*, rather than suffer it to come out. The consequence of the repeated strokes of the empty card against the full one, must be a distribution of the cotton more evenly on the surface, and if one card be then drawn in the *opposite* direction across the other, it will, by virtue of the inclination of its wires,

take the whole of the cotton out of that card, whose inclination is the contrary way.

In this mode, the operation of carding was formerly performed by hand with sheets of card nailed upon thin boards, which were drawn and scraped against each other, till the cotton or wool was evenly diffused over the surface, and freed from all the knotty or entangled parts. One of the cards being then turned and applied in an inclined position, so as to scrape with one edge over the surface of the other card, in the direction of its teeth, the cotton was, by a particular manœuvre, stripped off and coiled up into those short soft rolls which we have spoken of already under the name of *cardings*. Such, in all probability, was the process employed with little alteration, during the five last centuries in the woollen manufacture of this kingdom, and applied at subsequent periods to the preparation of cotton. The use of cards was most likely derived from the Netherlands, at or before the time our woollen manufactures were improved by the emigration of Flemish weavers to this country, during the reign of Edward III.

They continued to be imported hither till the year 1463, when the tradesmen and manufacturers of London, and other parts of England, having made heavy complaints to parliament of the obstruction to their own employment by the introduction of various foreign manufactured wares, an act was passed in the third year of Edward IV., prohibiting *wool-cards*, and various other articles of iron, steel, copper, &c. from being imported into this kingdom.

The hand-cards were succeeded by stock-cards, and these again by cylinder cards, as we have already observed, which were first attempted about the year 1763.

This machine consisted of two or more large cylinders covered with cards, revolving in opposite directions, and nearly in contact with each other, and surmounted by other smaller cylinders covered in like manner, by whose revolutions in various directions, and with different velocities, the cotton was carded and delivered to the last or finishing cylinder, from which it was stripped off by different contrivances. The cards were nailed on in stripes, or sheets of six or eight inches broad, and the margin of each sheet in which the nails were driven, being destitute of teeth, formed so many intervals or furrows across the surface of the cylinder.

The cotton was stripped off first by hand, as in Mr. Peel's machine, and afterwards by a fluted cylinder, or by a roller armed with slips of tin-plate or iron, standing erect like the floats of an undershot wheel, and which revolving quicker than the card, and in close contact with it, scraped off the cotton in distinct portions from each stripe or sheet, which fell into a receptacle below. This was a harsh and rude operation, and rubbed and injured not only the carding, but the cards themselves. Mr. Arkwright substituted for the fluted cylinder a plate of metal finely toothed at the edge, and moved in a perpendicular direction rapidly up and down by a crank.

The slight, but reiterated strokes of this comb, acting on the teeth of the cards, detached the cotton in a fine and uniform fleece. On the finishing cylinder also, narrow fillet-cards, as they are termed, wound round in a spiral form, were substituted for the ordinary cards nailed across.

The *continuity* of the fleece was thus preserved, which was destroyed before by the intervals or furrows we have alluded to, and being gradually contracted in its size, by passing through a kind of funnel, and flattened or compressed between two rollers, was delivered into a tin can in one *continued, uniform, perpetual carding*, so long as the machine continued in motion, and was supplied with the raw material.

This is, without exception, one of the most striking and beautiful operations in the whole process of spinning. Mr. Arkwright's right to the invention of the crank and comb was the disputed point at the last hearing of this cause, and the evidence which he was unprepared to meet having proved to the satisfaction of the jury, the prior claim of a mechanic, named Heyes, his exclusive right, not only to this improvement, but to all others included in the same patent, was cancelled by the judgment of the court. How far Mr. Arkwright would have been able in the event of another hearing to have disproved the evidence thus unexpectedly brought forward, is not easy to determine. That the crank had been applied in some way or other, prior to the date of Mr. Arkwright's patent, though in a much less efficacious and approved manner, we believe will admit of the fullest proof, and this circumstance, in a case in which the interest of a great body of manufacturers was deeply concerned, and was opposed only by that of a single individual, would, in all probability, have confirmed the former decision in a court already weary of the discussion.

The improvement, as far as Mr. Arkwright was concerned, was original, and undoubtedly his own, and bears evident marks of that genius and happy invention which so strongly characterize every part of his machinery. He was anticipated in a single idea before it was matured and brought forth, and in this instance lost the fruits of his industry and talents. His claim to the spiral cards, which produce the endless, or perpetual carding, has however never been disputed. At the same time Mr. Arkwright brought forward other machines peculiarly adapted to the preparation of the materials for his own mode of spinning, and founded on the principle of his former invention. The first of these, in the series of successive operations, is the *drawing frame*.

This machine consists of a system of rollers similar to those before described in the twist frame, revolving with different velocities, either from the variation of size in the pairs of rollers, their performing a different number of revolutions in the same space of time, or from both these causes united. Three or more cardings coiled up in deep tin cans are applied at once to these rollers; in their passage through which, they not only coalesce so as to form one single *drawing*, but are also drawn out or extended in length. This process is several times repeated; three, four, or more drawings, as they are now termed, being united and passed between the rollers; the number introduced being so varied, that the last drawing may be of a size proportioned to the fineness of the thread into which it is intended to be spun. By this operation, the fibres of the cotton are drawn out longitudinally, and disposed in an uniform and parallel direction, and all inequalities of thickness are done away by the frequent doubling or joining of so many different lengths.

A third machine was contrived by Mr. Arkwright for giving the necessary degree of twist to these prepared lengths of cotton. In the state in which it comes from the drawing frame, it has little strength or tenacity, and is received into similar deep cans, from whence it was passed through the rollers. To enable it to support the operation of winding, it is again passed through a system of rollers similar to those in the last machine, and received in a round conical can revolving with considerable swiftness. This gives the drawing a slight twisting, and converts it into a soft and loose thread, now called a roving, which is wound by the hand upon a bobbin, by the smaller children of the mill, and then carried to the spinning or twist frame, of which we have already spoken.

Such are the inventions and improvements for which we are indebted to the genius of Mr. Arkwright, and which compleat a ſeries of machinery, ſo various and complicated, yet ſo admirably combined and well adapted to produce the intended effect in its moſt perfect form, as to excite the admiration of every perſon capable of appreciating the difficulty of ſuch an undertaking. And that all this ſhould have been accompliſhed by the ſingle efforts of a man without education, without mechanical knowledge, or even mechanical experience, is moſt extraordinary, and affords a ſtriking inſtance of the wonderful powers diſplayed by the human mind, when its powers are ſteadily directed to one object.

Yet this was not the only employment of this eminent man, for at the ſame time that he was inventing and improving the machinery, he was alſo engaged in other undertakings, which any perſon, judging from general experience, muſt have pronounced incompatible with ſuch purſuits. He was taking meaſures to ſecure to himſelf a fair proportion of the fruits of his induſtry and ingenuity; he was extending the buſineſs on a large ſcale; he was introducing into every department of the manufacture a ſyſtem of induſtry, order, and cleanlineſs, till then unknown in any manufactory where great numbers were employed together, but which he ſo effectually accompliſhed, that his example may be regarded as the origin of almoſt all ſimilar improvements.

When it is conſidered, that during this entire period he was afflicted with a grievous diſorder (a violent aſthma) which was always extremely oppreſſive, and threatened ſometimes to immediately terminate his exiſtence, his great exertions muſt excite aſtoniſhment. For ſome time previous to his death, he was rendered incapable of continuing his uſual purſuits, by a complication of diſeaſes, which at length deprived him of life, at the Rock Houſe, Cromford, on the 3d of Auguſt 1792, in the 60th year of his age.

The honour of knighthood was conferred on him in December 1786, on the occaſion of preſenting an addreſs to his majeſty.

In the infancy of the invention, ſir R. Arkwright expreſſed ideas of its importance, which to perſons leſs acquainted with its merits appeared ridiculous, but he lived long enough to ſee all his conceptions more than realized in the advantages derived from it, both to himſelf and his country; and the ſtate to which thoſe manufactures dependant on it have been advanced ſince his death, makes all that had been previouſly effected appear comparatively trifling.

The ſyſtem of ſpinning introduced by ſir Richard was found moſt particularly applicable to the production of thread for warp, whilſt the Jenney of Hargreaves was chiefly employed in ſpinning the woof, or weft, for the coarſe kinds of which it was better adapted, indeed, than the more perfect machine of ſir Richard.

On theſe machines were ſpun for ſome years after their introduction all the twiſt and weft in the kingdom; the uſe of the Jenney has, however, ſince been almoſt wholly ſuperſeded by a third machine, called a Mule, for the invention of which we are indebted to the ingenuity of Mr. Samuel Crompton of Bolton.

The mule was invented about the year 1776, during the term of ſir Richard's patent right, and did not on that account come into general uſe till after its expiration. It is a compound of the two machines of Arkwright and Hargreaves, and is conſidered, as its name imports, as the offſpring of the twiſt frame and Jenney. It conſiſts of a ſyſtem of rollers like thoſe of the twiſt frame, through which the roving is drawn and received upon ſpindles, revolving like thoſe of the Jenney, and from which it acquires the twiſt. The carriage on which the ſpindles are diſpoſed is moveable, and receding from the rollers ſomewhat quicker than the thread is delivered, draws or extends it in the ſame manner as is done by the Jenney. See Mule.

This compleats the ſeries of machines now in uſe, and is the only important diſcovery in ſpinning ſince the invention of ſir Richard Arkwright, on which indeed its chief merit is founded.

Of its excellence, and alſo of thoſe other machines employed in the different preparatory proceſſes, ſome idea may perhaps be formed, when it is ſtated that a pound of fine cotton has been ſpun on the mule into 350 hanks, each hank meaſuring 840 yards, and forming together a thread 167 miles in length.

Hitherto we have entered only into ſuch details of the different proceſſes of ſpinning as were neceſſary to elucidate the hiſtory of their invention, and exhibit both the ſources and progreſs of the various improvements.

The operations which cotton undergoes in its paſſage from the raw material to the ſtate of thread, are various and multiplied in proportion to the fineneſs required, and the different uſes to which it is deſtined.

If we analize theſe operations, they reſolve themſelves into the following; Batting, carding, doubling, drawing, and twiſting. The three latter are never performed ſingly, but are variouſly joined in the ſame machine; and the ſame elementary proceſſes are oftentimes repeated in different machines, with various and different effects.

With reference to theſe effects, the operations which cotton undergoes, may be denominated batting, carding, drawing, and doubling, roving, and ſpinning.

Batting, is that operation which prepares the cotton for carding, by opening and diſengaging the hard compreſſed maſſes, in which it comes from the bales.

It is performed by beating the cotton with ſticks on a ſquare frame, acroſs which are ſtretched ſmall cords, about the thickneſs of a gooſe quill, with intervals ſufficient to ſuffer the ſeed, leaves, and other adventitious matter to fall through.

When a hard matted or compreſſed maſs of cotton is ſmartly ſtruck with a ſtick, the natural elaſticity and reſiliency of its fibres, gradually looſen and diſengage them, and the cotton recovers by repeated ſtrokes all its original volume. During this operation the ſeeds, &c. which adhere, are carefully picked out by the hand, and the cotton rendered as clean as poſſible.

Batting is generally and beſt performed by hand, though the ſcarcity of hands and coſt of labour have rendered other contrivances neceſſary. For a deſcription of the batting machine, with other particulars relative to this operation, ſee Machine.

Carding, is that operation in which the firſt rudiments of the thread are formed. It is performed, as we have before ſtated, by cylinders covered with wire cards, revolving with conſiderable ſwiftneſs in oppoſite directions, nearly in contact with each other, or under a kind of dome or covering, the under ſurface of which is covered with ſimilar cards, whoſe teeth are inclined in a direction oppoſite to thoſe of the cylinder.

By this means the ſeparation of almoſt every individual fibre is effected, every little knotty or entangled part diſengaged, and the cotton ſpread lightly and evenly over the whole ſurface of the laſt or finiſhing cylinder, from which it is ſtripped by the contrivance we have already deſcribed.

For Jenney ſpinning, which is ſtill in uſe for the coarſer

kinds of thread, the cardings are ſtripped off in ſeparate lengths. The finiſhing cylinder is covered with the ordinary cards nailed on in ſtripes acroſs, and the cotton contained between the margins or intervals of each ſtripe, forms one carding, whoſe length of courſe depends on the width of the engine, or cylinder. When ſtripped off by the crank and comb, it forms a looſe and ſhapeleſs film, which falling on the ſurface of a plain wooden cylinder, the lower half of which revolves within a hollow ſhell or caſing, the cotton in its paſſage is rolled up and delivered at the other ſide in perfect and cylindrical cardings.

For mule or water ſpinning, the finiſhing cylinder is covered with ſpiral or fillet-cards, and the cotton being taken off in one continued fleece, and contracted by paſſing through the funnel and rollers, forms one endleſs and perpetual carding, which is interrupted only, or broken, when the tin can that receives it is compleatly filled.

In the Jenney carding, the fibres of the cotton are diſpoſed acroſs or at right angles to the axis of the carding; in the perpetual carding they are diſpoſed longitudinally, or in the direction of its length, and it is this circumſtance which renders the carding deſtined for mule or water ſpinning, inapplicable to the Jenney, and *vice verſâ*. For further details, and a deſcription of the carding engine, we muſt refer our readers to the article Engine.

Drawing, and *Doubling*, is one of the preparatory proceſſes for which we are indebted wholly to ſir Richard Arkwright, and belongs excluſively to the mule, or water ſpinning.

The doubling, or paſſing three or four cardings at once through a ſyſtem of rollers, by which they are made to coaleſce, is intended to correct any inequalities in the thickneſs of the cardings, and alſo to admit of their being frequently drawn out or extended by paſſing through the rollers. The effect of this frequent drawing is to diſpoſe the fibres of the cotton longitudinally, and in the moſt perfect ſtate of paralleliſm. The operation of carding effects this in a certain degree; yet the fibres, though parrallel, are not ſtraight but doubled, as may eaſily be ſuppoſed from the teeth of the cards catching the fibres ſometimes in the middle, which become hooked or faſtened upon them. Their diſpoſition is alſo farther diſturbed by the taker-off or comb, which ſtrips them from the finiſhing cylinder; and though the general arrangement of the fibres of a carding is longitudinal, yet they are doubled, bent, and interlaced in ſuch a way, as to render the operation we are now ſpeaking of abſolutely neceſſary.

When the cardings have been paſſed four or five times through the drawing frame, every fibre is ſtretched out at full length, and diſpoſed in the moſt even and regular direction; and though the average length of a fibre of cotton is not two inches, yet the finiſhed drawing, as theſe prepared cardings are now termed, has all the appearance of a lock of Jerſey wool, whoſe fibres, ſix or eight times as long as thoſe of cotton, have been carefully and ſmoothly combed.

Roving, is that operation by which the prepared cotton, as it comes from the carding engine, or drawing frame, is *twiſted* into a looſe and thick thread, and wound upon a ſpindle or bobbin.

In Jenney ſpinning, the cardings are roved without any other preparation, by a machine called a roving billy, for a deſcription of which, with other particulars relative to Jenney ſpinning, ſee Jenney.

In mule or twiſt ſpinning, the prepared carding or drawing, as it is termed, is again paſſed through a ſyſtem of rollers, and is twiſted, either by a rapidly revolving can, into which it is delivered from the rollers, or by a fly and ſpindle ſimilar to thoſe of the flax wheel; in the latter caſe it is wound on the bobbin by the machine; in the former it is received in the conical can in which it acquires the twiſt, and is afterwards wound upon bobbins by the ſmaller children of the mill.

Sir Richard Arkwright always employed the revolving can, and it is ſtill employed in many of the firſt mills in the country. The roving frame with fly and ſpindle, which is in fact nothing more than the twiſt frame of ſir Richard, is now however very generally in uſe, eſpecially ſince later improvements have removed objections to the machine, which rendered its uſe heretofore inconvenient. See Frame.

The operations through which the thread paſſes after it has received the firſt twiſt are various, and depend greatly on the uſe it is intended for.

The finer it is required, the oftener it is drawn out and twiſted, till by degrees, as in the proceſs of wire-drawing, it is brought down to the fineneſs required. The rovings are therefore diſtinguiſhed into firſt, ſecond, and third, according to the number of operations they have gone through.

Spinning, is the laſt operation which the thread undergoes in the ſeries of proceſſes employed in converting it into thread, and is that in which it receives the final extenſion and twiſting.

It is performed either on the Jenney, twiſt frame, or mule. Of theſe machines we have already ſpoken generally, and alſo of the nature of their operation; for further and more particular details, we muſt refer our readers to their proper heads.

Such are the operations by which the raw material is brought into the ſtate of thread, and ſuch the improvements by which the cotton manufacture of this kingdom has arrived at its preſent unexampled ſtate of proſperity. We cannot give our readers a better idea of the effects immediately reſulting from theſe various improvements and diſcoveries, than by the following extracts from a pamphlet, publiſhed in the year 1788, intitled, "An important Criſis in the Calico and Muſlin Manufactures of this Country explained;" the purport of which was to warn the nation of the bad conſequences which would reſult from the rivalry of the Eaſt India cotton goods, which then began to be poured into the market in increaſed quantities, and at diminiſhed prices.

The author aſſerts, that, not above 20 years before the time of his writing, the whole cotton trade of Great Britain did not return 200,000*l*. to the country for the raw material, combined with the labour of the people; and at that period, before the introduction of the twiſt frame and Jenney, the power of the ſingle wheel could not exceed 50,000 ſpindles:

In 1787, the number of cotton mills, as near as intelligence could be procured, was as follows:

In Lancaſhire	41	Flintſhire	3
Derbyſhire	22	Pembrokeſhire	1
Nottinghamſhire	17	Lanerkſhire	4
Yorkſhire	11	Renfrewſhire	4
Cheſhire	8	Perthſhire	3
Staffordſhire	7	Edinboroughſhire	2
Weſtmorland	5	Reſt of Scotland	6
Berkſhire	2	Iſle of Man	1
Reſt of England	6		
	119		24

The whole being 143, the coſt of which was eſtimated at	- -	£715,000
There were at the ſame time 550 mules, and 20,700 Jennies, containing, together with the water frames, 1,951,000 ſpindles; the coſt of which, and of the auxiliary machinery, together with that of the buildings, is ſtated to have been at leaſt	- - -	285,000
The total expenditure being		£1,000,000

Theſe eſtabliſhments, when in full employment, were eſtimated to produce as much cotton yarn as could be ſpun on the ſingle ſpindle by a million of perſons; and inſtead of diminiſhing the employment of the people as was apprehended, they called vaſt numbers from idleneſs to comfortable independence. At this time they were ſuppoſed to give employment to 26,000 men, 31,000 women, and 53,000 children in ſpinning alone; and in all the ſubſequent ſtages of the manufacture the number of perſons employed, was eſtimated at 133,000 men, 59,000 women, and 48,000 children, making an aggregate of 159,000 men, 90,000 women, and 101,000 children, in all 350,000 perſons employed in the different branches of the cotton manufacture.

The quantity of the raw material conſumed in this manufacture, which in 1781 did not amount to 6,000,000 lbs., in the year 1787 exceeded 22,000,000. The aſtoniſhing rapidity of this increaſe, which will be more clearly ſhewn by the following ſtatement, is to be in a great meaſure attributed to the extenſion of the manufacture to the goods of India, particularly calicoes and muſlins.

Cotton uſed in the Manufactures of Great Britain.

Years.	Pounds.	Suppoſed value when Manufactured
1781	5,101,920	£2,000,000
1782	11,206,810	3,900,000
1783	9,546,179	3,200,000
1784	11,280,238	3,950,000
1785	17,992,888	6,000,000
1786	19,151,167	6,500,000
1787	22,600,000	7,500,000

The cotton imported for the manufacture of 1787, was of the following growth:

Britiſh Weſt India, eſtimated at	6,600,000 lbs.
French and Spaniſh ſettlements	6,000,000
Dutch Settlements	1,700,000
Portugueſe ditto	2,500,000
Eaſt India, procured from Oſtend	0,100,000
Smyrna and Turkey	5,700,000
	22,600,000

The application of this cotton to the different branches of manufacture was ſuppoſed, by intelligent perſons, to have been as follows:

Candlewicks -	1,500,000 lbs.
Hoſiery -	1,500,000
Silk and Linen mixtures	2,000,000
Fuſtians -	6,000,000
Calicoes and Muſlins -	11,600,000
	22,600,000

In the branches applicable to muſlin and calico alone, it was calculated that employment was given in England and Scotland to 100,000 men and women, and at leaſt 60,000 children.

The progreſs of the Iriſh in the ſame line of induſtry muſt not be overlooked, and the laudable and ſpirited exertions of captain Robert Brooke deſerve to be more particularly noticed. In the year 1780, that gentleman eſtabliſhed a cotton manufactory on his lands ſituated on the great canal about 18 miles W. of Dublin. In 1782, the government of Ireland, underſtanding that ſome of the manufacturers of Mancheſter intended to remove to America, and carry their machinery with them, found means to perſuade them to go to Ireland, and gave captain Brooke about 3000 *l.* for ſettling them in houſes upon his lands, and they afterwards advanced him 32,000 *l.* upon intereſt and ſecurity, that he might give employment to a great number of weavers who were then ſtarving and riotous for want of employment in Dublin. By means of theſe and other acquiſitions of inhabitants, the manufacturing village which was called Proſperous, conſiſted now of ſeveral hundred houſes, erected on a ſpot where, in the year 1780, there ſtood one ſingle hut; and the manufacture gave employment to about three thouſand men, women, and children. Beſides captain Brooke's, which was the principal one, there were at this time ſeveral other manufactures of cotton eſtabliſhed in various parts of Ireland by the ſpirited exertions of individuals, and the liberal encouragement of parliament.

It may be proper here to obſerve, that two ſpinning mills were eſtabliſhed in France, near Rouen, under the direction of Mr. Holker, an Engliſh manufacturer, who, with his partners, was aſſiſted and patronized by the French government: and it was not long before Arkwright's machinery was even tranſported acroſs the Atlantic, and a ſpinning mill erected in Philadelphia.

Calicoes were firſt brought hither from India in the year 1631, and derived their name from the province of Calicut, where they were chiefly made or exported. They were firſt manufactured in this country about the year 1772, or 1773. Various attempts had been made previous to this time to manufacture cloth with cotton warp or web, but owing to the imperfection of the twiſt or yarn, ſpun either on the one thread wheel or Jenney, they all proved unſucceſsful. The warp was too flimſy, and unable to ſupport the ſtretch or tenſion of the loom, or when it did, too ſoft to form a cloth of firm and uſeful texture. The improvements that rapidly followed the introduction of machine ſpinning, and more eſpecially thoſe of ſir Richard Arkwright, ſoon remedied this defect; yet, though moſt excellent yarn or twiſt was produced, the manufacturers could not at firſt be prevailed upon to weave it into calicoes. Mr. Strutt, therefore, of Derby, in conjunction with Mr. Samuel Need, both in partnerſhip with ſir Richard Arkwright, attempted the manufacture of calicoes about the year 1773, and proved ſucceſsful; yet after a large quantity had been made, it was diſcovered that they were ſubject to double the duty (*viz.* 6*d.* per yard) of cottons with linen warp, and when printed were prohibited. They had therefore no other reſource than to aſk relief of the legiſlature, which after great expence and oppoſition, they at length obtained, and thus laid the foundation of a branch of manufacture which has ſince become one of the moſt important in the kingdom.

The manufacture of calicoes was begun at Blackburn, in Lancaſhire, about this period alſo, at firſt from twiſt ſpun in the neighbourhood upon Jennies, but afterwards principally

from the water twift. The goods manufactured here before the introduction of calicoes, were *Blackburn greys*, made of cotton woof, but linen warp of Hamburgh or Irifh yarn, but chiefly of the latter. Thefe goods, which were the calicoes of that day, were manufactured as early as the year 1727, at which period all the cotton goods, fuch as pillows, jeans, jennets, moft of the cords and thickfets were made with linen warp, and even the warps for dimities were half linen. The Blackburn greys were fold in the unbleached ftate to the calico-printers of London, and afterwards to thofe of Lancafhire and Chefhire, till the introduction of the real calico put a ftop to this manufacture about the year 1775.

Blackburn has fince become the great mart for calicoes, and the chief fource from whence the printers of Lancafhire, as well as thofe of London and Scotland, are fupplied.

The quantity manufactured, or rather fold there, (for the Blackburn houfes employ weavers in all parts of the furrounding country, and even at confiderable diftances) amounted a year or two ago to upwards of one million pieces annually. The quantity now made is perhaps lefs than this, but of finer quality, a larger capital is employed, and the manufacture is on the increafe.

The quantity of calicoes manufactured in the whole kingdom, not twenty years ago, was little more than half what the Blackburn market now affords, and it is probable that this forms but a fmall part of the quantity annually made in this country. They are chiefly printed into garments, fhawls, and furnitures, both for home confumption, and a confiderable foreign trade. The finer forts are worn as dreffes, white or plain, and large quantities are ufed for linings, and other purpofes for which the coarfer kinds of linen were formerly employed.

The lightnefs, as well as cheapnefs, of the calicoe, has rendered it a chief article of drefs amongft all claffes of people, and annihilated the manufacture of many of the lighter kinds of woollen and worfted ftuffs, formerly fo much in demand. The trade of Halifax, and the furrounding country, which confifted almoft wholly in fuch ftuffs, has gone entirely to decay, and been replaced by the manufacture of calicoes and other cotton goods: and fuch are the quantities now manufactured, more efpecially in the country around Colne, and thence to Bradford, that from 16 to 20,000 pieces are brought weekly to the Manchefter market; the produce of thofe diftricts which adjoin, or are included between thefe two towns.

To the fame improvements in fpinning which gave birth to the manufacture of calicoes, we are indebted for that of muflin, a branch not lefs important to the country than honourable to our pride and induftry as manufacturers. For this elegant article of drefs all Europe had long been tributary to India, where the manufacture has, through the long lapfe of ages, arrived at the greateft perfection. Muflins were firft introduced into this country by the Eaft India company, about the year 1670, before which time cambrics and Silefia lawns were worn, and fuch fine linens from Flanders and Germany, as were brought back in exchange for our woollen manufactures of various kinds exported thither in confiderable quantities. The manufacture was attempted at Paifley as early as the year 1700. A few looms were employed, but this trade was foon annihilated by the introduction of the goods of India. Eighty years afterwards a more fuccefsful rivalfhip commenced. Britifh muflins were firft fuccefsfully introduced in the year 1781, but were carried to no great extent till 1785, fince which period their progrefs has been rapid beyond all example. In the year 1787, it was computed, that not lefs than 500,000 pieces of muflin, including fhawls and handkerchiefs, were annually made in Great Britain. The manufacture has, from that time to the prefent, continued progreffively to increafe and improve, and bids fair to become the moft lucrative and extenfive of any in this country. The rapidity with which it approaches to perfection, and its furprifing extent in the fhort fpace of twenty years, are amongft the many important confequences that have refulted from the improvements in the art of fpinning.

By the cheapnefs and fuperior quality of our yarn, we are enabled to employ thoufands of looms in the production of this elegant and ufeful article of drefs, to keep in this country millions of fpecie which was heretofore fent to the Eaft to purchafe this commodity, and to clothe ourfelves with this fabric at one-third of the expence formerly required.

The demand for, and the ufe of this article, are proportionate to its cheapnefs and elegance, and it is not difficult to fee that it will become a ftaple manufacture of this country.

Glafgow and Paifley in Scotland, and Bolton in Lancafhire, are the chief feats of this manufacture, which is however confiderably extended over many other parts of the country. India ftill maintains her fuperiority in the finer kinds of muflin, fome of which of moft exquifite beauty and finenefs are fold in this country, as high as ten or twelve guineas *per* yard. In productions like thefe, no rivalfhip can exift; in India they are looked on as mafter pieces of art, and the time employed by an Indian weaver in their production would ruin an European.

The common kinds, or fuch as are more adapted to general ufe, are alfo preferred by our Englifh ladies to thofe of home manufacture, on the fcore of their enduring greater hardfhips and retaining their colour, or rather whitenefs, better. This excellence, which exifts to a certain degree, is the refult of no fuperiority in the manufacturing proceffes, but in the raw material, of which that of India is the fineft and beft in the world.

Muflins were manufactured at Zurich and St. Gall in Switzerland long before we fucceeded, yet fuch were the advantages which the improvements in fpinning afforded us, that till within thefe few years (during which the unfettled ftate of the continent has interrupted, and in fome countries annihilated, all commercial intercourfe) we fupplied all Europe with muflins, not only of Indian, but Britifh manufacture.

Nankeens and ginghams were manufactures, which, without the improvements of the fpinner, could not poffibly have fucceeded.

Thefe articles, like the two preceding, were formerly brought from the Eaft exclufively. Fuftians, dimities, jeans, quiltings, velvets, velverets, velveteens, and a variety of cotton goods, which the limits of our article will not allow us to particularize, have been improved to fuch a pitch, that Manchefter has fupplied all Europe with thefe fabrics.

Cotton hofiery forms no inconfiderable part of this immenfe manufacture, and it was the demand for cotton thread for the ftocking weavers, that urged forward the improvements of Mr. Arkwright, and held out fuch ftrong inducements to thofe whofe affiftance firft enabled him to give his invention to the world.

Exclufive of thefe various manufactures, great quantities of twift were exported to the continent, and a confiderable part of the yarn fpun in Manchefter, before the late difaftrous occurrences in Germany, was employed in the foreign loom. It was this demand for twift, which our continental rivals were unable to produce of equal quality

or price with ours, which raised this branch of the cotton manufacture to a state of prosperity, of which some idea may be formed, when it is stated that the various establishments for spinning only in this country, when in full activity, give employment to near 180,000 persons, a number little short of that which is employed in France in all the different branches of the cotton mannfacture together, and which, according to the report of Chaptal, late minister of the Interior, amounts to near 200,000

The value of these improvements in spinning was so obvious and so important, that it is not surprising they were soon diffused over the continent, notwithstanding every precaution used to prevent it. By the emigration of mechanics, and the clandestine exportation of machinery constructed here, our neighbours soon became possessed of our improvements, and had we paused in our exertions, the superiority we had acquired would long ere this have passed away. France, as we have just observed, has a great population employed in the manufacture of cotton. Prussia and Germany have many and increasing establishments, and in the two former countries, and in the hereditary dominions of the emperor of Germany, our piece goods have been long prohibited.

Our spinners however, by their ingenuity, and the improvement and perfection of their machines, have still kept the lead; and the attention of our manufacturers is now directed to the perfection of those operations more immediately connected with the labours of the loom, in which, till within these few years, little has been done. Every day brings forth new discoveries, and it is not difficult to see that what has already been atchieved, and what, from the general spirit of improvement which is now abroad, must inevitably follow, will soon place us far beyond the reach of competition in the manufacture of cotton goods, and give us advantages greater than ever we enjoyed since its first establishment in this country. Before we enter into such a detail of these improvements however, as will enable our readers fully to comprehend their nature and extent, it will be proper to take a short view of the different operations and processes through which the thread passes in its progress from the hands of the spinner to the loom.

The thread is of two kinds, viz. *twist*, so called from its being harder twisted than the other, forming a stouter thread, and used for the web or warp of piece goods, and *weft*, which is a looser, softer thread, and used for the woof. The *weft* is delivered to the weaver in small oblong rolls called *cops;* in the state they are stripped off the spindles of the mule or Jenney. When these are used, a small pointed piece of wood or skewer is carefully passed through the axis of the cop into the place formerly occupied by the spindle, and one end of it being held between the teeth, the thread is wound off the cop upon the weaver's bobbin by a wheel somewhat smaller in size, but the same in principle as the common one thread wheel on which all the spinning was formerly performed.

This is generally done by children, and the bobbins are then ready for the shuttle. Twist undergoes several operations before it is ready for the loom. It is delivered by the spinner either in *hank*, or *cop*.

Hank twist is that which is spun on the water frame, from the bobbins of which it is *reeled* into hanks of a determinate length, each measuring 840 yards. The value and fineness of the thread are proportionate to the number of hanks in a pound, and they are denominated by numbers, as Nos. 20, 50, 100, &c. which express the hanks which a pound of twist contains. In this state it is generally *sized*, an operation which is intended to give additional strength and tenacity to the thread, and enable it to support the different operations in its passage to the loom. It consists in impregnating the thread fully with thin size, chiefly formed of wheat flour boiled in water, with the addition of a little glue. The twist is carefully worked in this and afterwards wrung and dryed. The thread acquires considerable strength by this operation, and the loose fibres are all firmly attached or glued to its surface. It is then delivered to the winder.

Winding is that operation by which the thread is transferred to the warping bobbin, either from the cop, hank, or twist frame bobbin.

Formerly this was chiefly done by females, and the work was carried home and performed by any of the family not engaged in domestic concerns, on a small wheel that turned two bobbins at a time.

This mode is still in use, but the work has been greatly abridged and facilitated by the use of machines of various constructions, for a description of which, see MACHINE.

Cop twist is that which is spun on the mule or Jenney. It is reeled only occasionally to ascertain its value and fineness, and is delivered in cops to the winder.

The next operation is that of *warping*, or the formation of the web. The machine on which this is performed is an octagonal prism five or six feet high, and somewhat less in diameter, revolving vertically, and put in motion by a band and pulley placed under the seat of the warper. The bobbins which furnish the thread are suspended horizontally in a frame on one side. Twenty-eight or thirty threads, forming together a system called a *half beer*, are wound round the prism in a spiral form from top to bottom. The machine is then turned the contrary way, and the thread wound round the prism upwards from bottom to top, and this is repeated backwards and forwards till a sufficient number of *half beers* have been wound to form a web of the breadth required.

When finished, and the ends properly secured, the whole is wound off and coiled upon the hand into a round ball called the *warp*. For further particulars of this operation, and a description of the machine, see MILL.

If the thread has been previously sized in the hank, it is now ready for the loom, but if the warp is made of cop twist, that operation is next performed.

The warps are boiled several hours in water till they are thoroughly penetrated and softened; after draining some time they are then uncoiled and worked in the size till fully impregnated, after which the superfluous size is squeezed out, and they are suspended on poles to dry: the warp is then ready for the loom.

Without this operation of sizing, which, as we have before observed, gives strength and tenacity to the thread, it would not support the friction of the loom. Two threads are passed between each dent of the reed, and at each stroke of the treadle one ascends whilst the other descends. There is therefore a constant friction of the threads upon each other, as well as against the teeth of the reed. The motion of the reed itself also backwards and forwards, and of the healds up and down, is very severe upon the warp, and unless it has been well penetrated by the size, and its fibres well cemented or glued together, this continual rubbing is sufficient to destroy its texture.

Good sizing prevents this, but it is still further aided by another operation called *dressing*, which is performed by the weaver himself after the warp is got into the loom. This consists first in applying with a brush a kind of paste made

of wheat flour well boiled, to which is often added a small portion of common salt; sometimes of potash, and sometimes even a little tallow.

It is in fact a repetition of the operation of sizing, with this difference, that the dressing is applied chiefly to the surface of the thread, which is slightly smeared with the paste, and brushed uniformly in one direction from the healds to the beam, by which means the loose fibres are all disposed evenly one way, and firmly glued fast to the thread.

In summer the warp is dried simply by fanning it, but in winter, and in damp cold weather, a hot iron is lightly passed over it. It is then dressed again with a brush dipped in tallow or butter, with which it is slightly greased. This gives suppleness and smoothness to the thread, and greatly diminishes the friction of the healds and reed. As such a portion of the warp as is extended between the healds and beam can alone be dressed at one time, this is woven, and the dressing repeated again upon another portion, and so on alternately dressing and weaving till the whole of the web is finished.

Various improvements on these different processes have taken place during the last six or eight years, which have made greater or less progress in proportion to their importance. We shall enumerate, therefore, not only those of recent date, but such as, though known some time, have not been generally adopted.

The weaver's bobbin is still wound by hand in the manner already described, though the use of a small machine, by which twenty bobbins or upwards are wound at once, is daily gaining ground. They are to be seen now in almost every weaver's cottage where several looms are employed. This labour is further abridged by a very ingenious contrivance for which a patent has been obtained. The cops, instead of being wound, are compressed or squeezed till they are small enough to enter the shuttle. The winding here is done away, and the cops thus compressed are preferred, by the weavers to the common bobbin. In those large establishments where the different processes, such as spinning and weaving, are carried on together, the cops are spun small enough to enter the shuttle without compression. The weft is transferred at once from the spindle of the mule to the weaver's shuttle, and the time and waste of winding, and even of compressing, saved entirely.

On the same principle also, a considerable reduction has been made in the labour of reeling and winding twist. Till within a late period, the practice has uniformly been to reel it into hanks from the bobbin it was spun on, to size it in the hank, and then wind it for warping. An obvious reduction of this labour is to warp it directly from the bobbin it is spun on, and size it in the warp like cop twist. For reasons, however, which it will not be necessary here to enter into, this has been found impracticable. It is, however, transferred to the warping bobbin without the intermediate labour and waste of reeling, and the sizing is done in the warp.

Considerable improvements in the mode of sizing have been made within these few years, especially in the sizing of warps.

Formerly, the practice was to work the warp in the warm size by the hand, the heat of which was of course limited to that degree which could be readily borne by the workman. Experience having proved that the hotter the size, the more evenly and perfectly was the warp penetrated, various contrivances were adopted for applying it at a high temperature. Amongst others are oblong troughs furnished with several pairs of rollers, through which the warp passes, and is strongly compressed whilst immersed in the hot size. Mr. Marsland's idea of placing the twist in an exhausted receiver, and admitting the hot size, promises considerable advantages in some cases, and when the plan has been matured, will no doubt be susceptible of many applications.

But the greatest improvement that has been made in these different processes, and one that must eventually effect a compleat revolution in the whole system, is Messrs. Ratcliffe and Ross's mode of dressing. Hitherto this operation has been performed by the weaver in the manner we have already described, at the expence of one-third of his time and labour. As it is only possible for him to dress at once as much of the work as is contained between the healds and beam, he is scarcely got settled to his work, after each operation, before he is again called off to dress another portion. By this continual interruption of one species of labour by another totally different, it must be obvious to every one, that not only much time is lost, but that the labour itself cannot be equally well performed.

There is a delicacy and certainty of touch in weaving, dependant on long habit and experience, and on which the evenness and goodness of the cloth depends.

If the force with which the woof or weft is driven up by the reed, be not always alike, if it is greater at one time and less at another, the cloth will be thicker and thinner at those places, and such is the nicety on which this depends, that the most experienced weaver, after an interruption of some hours, cannot at once regain it.

Messrs. Ratcliffe and Ross dress the whole of the warp before it is wound upon the beam, the labour of the weaver is therefore uninterrupted, and his attention directed solely to one object. This alone is a great point gained, but it is attended also by other, not less important, advantages. Great part of the intellectual skill required in weaving is in the dressing and beaming of the warp; the mere mechanical part of throwing the shuttle, &c. is soon acquired, even by a boy. A more accurate division of labour, by reducing the beaming and dressing to a system by which they are better, more economically, and more expeditiously performed than before, has removed the great difficulty in the art of weaving, and rendered it in a great measure the employment of children.

From what we have already said, it will appear that the object in dressing and sizing is nearly the same, and Messrs. Ratcliffe and Ross, by this improved mode of dressing, have succeeded in reducing these operations to one. They have gone still further; they have done away the necessity of warping, by forming the web at once from the bobbin, and thus reduced the warping, sizing, dressing, and beaming, to one operation. A thousand bobbins and upwards supply the materials for the warp, which in its progress is properly disposed and arranged, sized, dressed, and finally wound upon the beam. This improvement, which may justly be regarded as the most important that has taken place in weaving since the invention of the fly shuttle fifty years ago, must in the end effect a compleat change in the system of labour. Great however as its advanatges are, some time must necessarily elapse before it can be accommodated to general use. In large establishments, where the different processes of the manufacture are carried on together, such as spinning, weaving, and the labour immediately connected with them, it has been adopted with the happiest success, but the weaving in this country is chiefly done in the cottages of the poor, and to their use the costly and bulky apparatus of Messrs. Ratcliffe and Ross is not adapted.

To derive all the advantages possible from this improvement, therefore, it will be necessary either that the weaving

be done in large ſhops, to each of which a dreſſing machine may be attached, or that the warps be delivered to the country weavers ready dreſſed and wound upon the beam. The former plan is daily gaining ground, and perhaps it is not difficult to foreſee, that at no very diſtant period all the weaving of the country will ſhare the fate of the ſpinning, and quit the cottage for thoſe larger eſtabliſhments in which it will be ſuſceptible of better management, and more accurate diviſion of labour.

The laſt improvement, which we ſhall notice in the manufacture of cotton, and which, when once eſtabliſhed, will compleat what Arkwright has ſo happily begun, is that of weaving by machinery. Various attempts have been made of late years to apply the great moving powers, ſteam, and water, to the common loom. Mr. Dolignon, many years ago, conſtructed a loom adapted, as we are told, to the manufacture of all kinds of cloth. It might be wrought by the power of wind, water, ſteam, or animal ſtrength, and poſſeſſed an inſtinctive capacity (if we may be allowed the phraſe) of knowing when any thread of the weft or warp was broken, in which caſe the loom ceaſed its motion, thus calling on the attendant to repair the damage, which being done, it immediately went on as before; ſix of theſe looms might be attended with eaſe by a girl of ſixteen, or an aged or infirm perſon of either ſex. The inventor did not live to reap the fruit of his labour, nor to introduce his machine properly to the world. He died ſoon after its completion, when he had brought it to a ſtate of perfection ſatisfactory to himſelf, and with him periſhed the reſult of his induſtry and talent. Such is the account which the friends of Mr. Dolignon give of this invention: ſince that time ſeveral other looms of ſimilar conſtruction have been invented.

Mr. Auſtin of Glaſgow has produced one, a model of which is depoſited at the houſe of the Society of Arts in the Adelphi, in favour of which numerous teſtimonies were tranſmitted to the ſecretary. In the year 1798, a loom on this conſtruction was ſet to work at Mr. Monteith's ſpinning works near Glaſgow, which anſwered the purpoſe ſo well, that a building was erected by Mr. Monteith for containing thirty looms, and afterwards another to hold about 200.

The model depoſited in the Adelphi is an improvement on thoſe firſt made for Mr. Monteith, whoſe name we do not however ſee amongſt the liſt of thoſe who bear teſtimony to its value. A loom of this kind, ſays the inventor, occupies only the ſame ſpace as a common loom. The expence is about one-half more. The reeling, winding, warping, beaming, looming, combing, dreſſing, fanning, greaſing, drawing bores, ſhifting heddles, rods, and temples, which is nearly one half of the weaver's work, together with the general waſte accompanying them; all which occur in the operation of the common loom, do not happen in this, which by its ſingle motion, without trouble, performs every operation after the ſpinning, till the making of the cloth is accompliſhed. One weaver and a boy are ſufficient to manage five looms of coarſe work, and three or four of fine work. The conſtruction of this loom is ſo complicated, that the ſociety have not, in their Tranſactions, given the public a drawing of it, conceiving that a model only could render it intelligible.

Other looms of a more ſimple, and conſequently of more uſeful conſtruction, have been invented by Meſſrs. Horrocks and Marſland of Stockport near Mancheſter, which, combined with the dreſſing machine of Meſſrs. Ratcliffe and Roſs, promiſe to be of conſiderable utility, and have already been tried on a ſufficiently extenſive ſcale by the inventors. The dreſſing machine, indeed, has removed the great difficulties in machine weaving, and without it nothing important or advantageous could have been accompliſhed. It has alſo rendered the machine loom itſelf of leſs importance, by ſimplifying the art of weaving ſo much as to render that the employment of boys, which was formerly entruſted only to experienced weavers. To the rapid extenſion of this improvement, however, there are objections at the preſent moment ariſing from moral as well as political conſiderations which muſt greatly retard its progreſs, and we muſt look to happier times for the proof of its general utility, and its final adoption or rejection.

The preceding ſketch, ſhort and imperfect as it is, will ſerve to convey ſome idea of this immenſe and important manufacture. Of the population at preſent engaged in it, and of its annual value, we have only ſuch conjectures to offer as are founded on thoſe materials which are within the reach of individuals, and unleſs government order ſuch an enquiry, it can only be eſtimated by the importation of cotton, which is for the moſt part manufactured at home.

Perhaps the manufacture of Scotland, as being in a narrow field, is more within the reach of obſervation than that of England; we therefore venture to lay before our readers, as being apparently an approximation to the truth, the following,

Eſtimate of the ſtate of the cotton manufacture in Scotland, made up in the year 1796 at Glaſgow, the centre of the principal commerce and manufactures of that kingdom.

39 water mills, which coſt for machinery and buildings 10,000 *l.* each - -		£ 390,000
and work	124,800 ſpindles	
1200 Jennies 84 ſp. each	100,800 at 6*l.* each	7,200
600 mules 144 ſp. each	86,400 at 30*l.* each	18,000
Total, working by day and night	312,000 ſpindles.	
Building for the Jennies coſt -		75,000
Capital veſted in machinery and buildings		£ 490,200
The yarn annually ſpun is valued at		£ 1,256,412
The cotton 4,629,043 lbs, average value 2*s.*		462,904
The people employed are eſtimated at 25,000 of both ſexes, young and old, but the greater part under 15 years of age, whoſe labour, aided by machinery, thus improves the value of the raw material in the firſt ſtage of manufacture. - - -		793,508
From which deduct wages eſtimated at		500,000
Remains for coſt, and wear and tear of machinery, and proprietors profits, the ſum of - - -		293,508
The annual value of calicoes and muſlins, now deſervedly eſteemed the ſtaple of Scotland, when finiſhed, including the exciſe duty on a part of them which are printed, and the coſt of tambouring and needle work on about a third part of them, was then eſtimated at		£ 3,108,549
Value of the cotton yarn as above -	£ 1,256,412	
Yarn got from England	520,000	
		£ 1,776,412

The wages of weavers, tambourers, needle-workers, the charges, the profits of the manufacturers, and the revenue paid to government, thus amounted to £1,332,137

Which great sum is produced by capital, ingenuity, management, and labour in the subsequent stages of the business.

The cotton manufacture in Scotland employs - -	38,815 weavers.
For winding warp and weft	12,938 women.
And supposing $\frac{1}{4}$ of the muslin adorned with needle work -	105,000 women.
and girls most children.	
Besides those employed in the spinning branch	25,000
Hence it appears that - -	181,753 persons

derive their immediate subsistence from the cotton manufacture in Scotland, and also a proportional number in England, employed in producing yarn to the value of 520,000 *l.*; besides the innumerable people of all classes concerned in providing necessaries and accommodations of every kind for that great multitude, and in constructing and repairing the machinery and buildings; and the cultivators of the cotton in the East and West Indies, seamen, merchants, &c. who are all wholly or partly supported by this most beneficial manufacture, by which the cotton is raised, taking the whole manufacture together, to about seven times the value it was of when imported.

The cotton manufacture has increased very much in Scotland since the year 1796. The imports of cotton into the kingdom in the year 1800, were nearly treble those of the year 1796. The printing business however appears to have declined a little, as may be inferred from the following

Account of the Calicoes, Muslins, Linens, and Stuffs, printed in Scotland in the years 1796 and 1800.

	1796			1800.	
	Rate of Duty	Yards.	Amount of Duty.	Yards.	Amount of Duty.
	d.		£ s. d.		£ s. d.
Foreign Calicoes and Muslins - -	7	141,403	4,124 5 1	78,868	2,300 6 4
British Calicoes and Muslins - -	$3\frac{1}{2}$	4,258,567	62,103 19 $1\frac{1}{2}$	4,176,939	60,913 13 $10\frac{1}{2}$
Linens and Stuffs - - -	$3\frac{1}{2}$	1,185,500	17,288 10 10	1,220,714	17,802 1 7

In England and Wales, on the contrary, the printing business has increased during the above period, as will appear from the following

Account of the Calicoes, Muslins, Linens, and Stuffs, printed in England and Wales in the years 1796 and 1800.

	1796.			1800.	
	Rate of Duty.	Yards.	Amount of Duty.	Yards.	Amount of Duty.
	d.		£ s. d.		£ s. d.
Foreign Calicoes and Muslins - -	7	1,750,270	51,049 10 10	1,577,536	46,011 9 4
British Calicoes and Muslins - -	$3\frac{1}{2}$	24,363,240	355,297 5 0	28,692,790	418,436 10 5
Linens and Stuffs - - -	$3\frac{1}{2}$	3,464,862	50,529 4 11	3,232,073	47,134 7 11

If we follow the calculation assumed in an estimate laid before a committee of the house of commons, that the duty is one tenth of the value, we may estimate the value of the British calicoes and muslins printed in England and Wales in 1796, at £3,552,972 0

And those in 1800 at 4,184,365 0

From these statements, which are official, it appears that in 1800 there were printed about a million and a half of calicoes and muslins in Great Britain, exclusive of linens, stuffs, and foreign calicoes. From that time, to the year 1806, the business has continued progressively to increase, the amount of duties on printed goods for that year being upwards of 600,000*l.*, which will bring the number of pieces printed nearly to two millions.

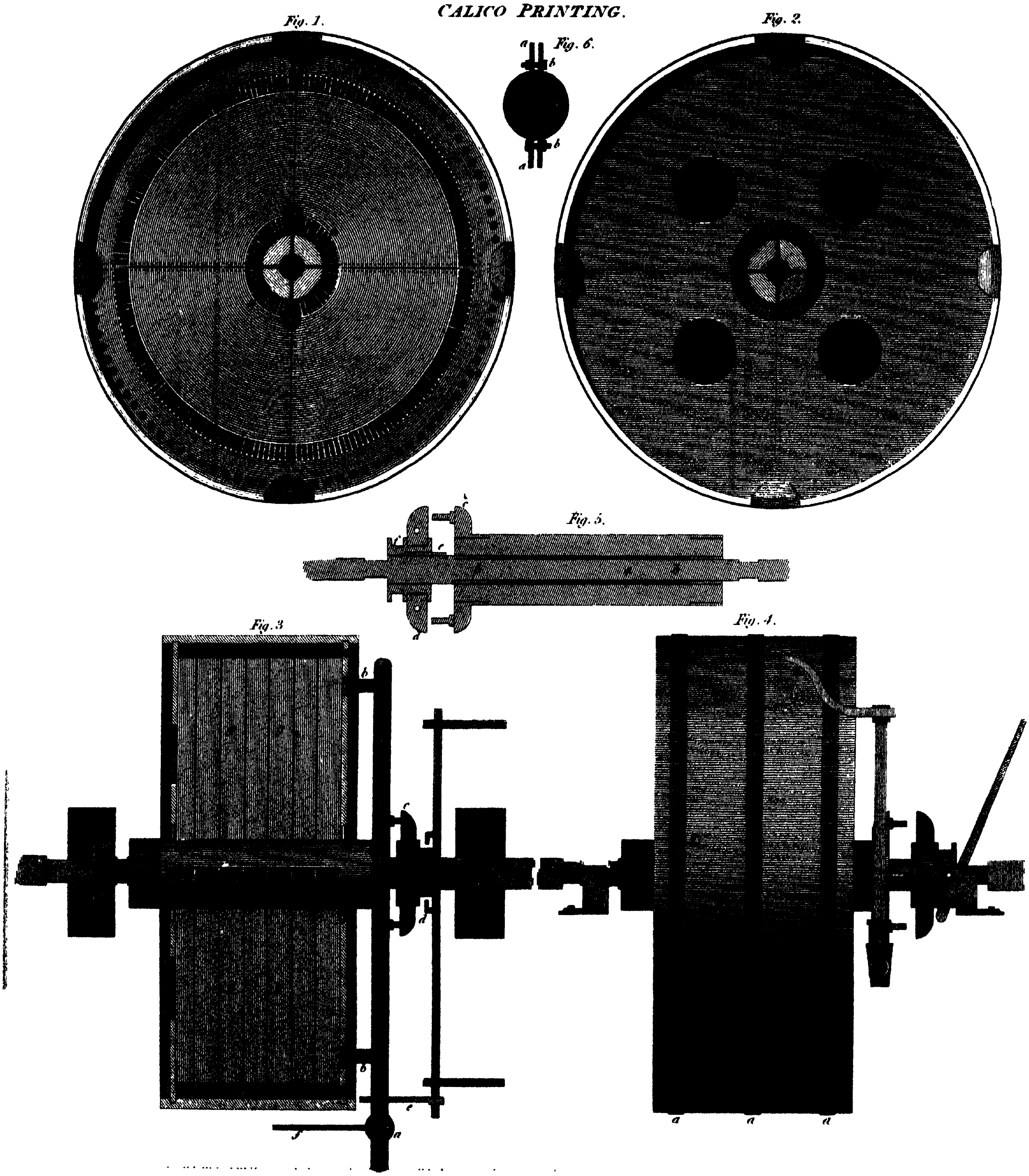
The quantity of white calicoes and muslins made in England and Wales, is certainly much greater than that of the printed; probably not less than three million pieces annually.

From the signatures to the petition of the journeymen calico-printers to the house of commons in the year 1806, it would appear that, in Great Britain and Ireland, the number is 7000; we suspect however that this number includes apprentices, and that the list also has been swelled, as is usual in such cases, by unfair means.

During the progrefs of the work we fhall have frequent opportunities of reverting again to the fubject of the cotton manufacture, and of fupplying thofe omiffions which, in a bufinefs of fuch magnitude and extent, when fubmitted to individual inveftigation, muft unavoidably occur. We fhall conclude therefore with obferving that, from the beft information we have been able to collect, and from calculations founded on the quantity of the raw material imported into the country and of goods exported, it appears that the cotton manufacture of thefe realms gives employment to 800,000 perfons, and that its annual value is upwards of 30 millions.

COTTON MANUFACTURE

CALICO PRINTING.



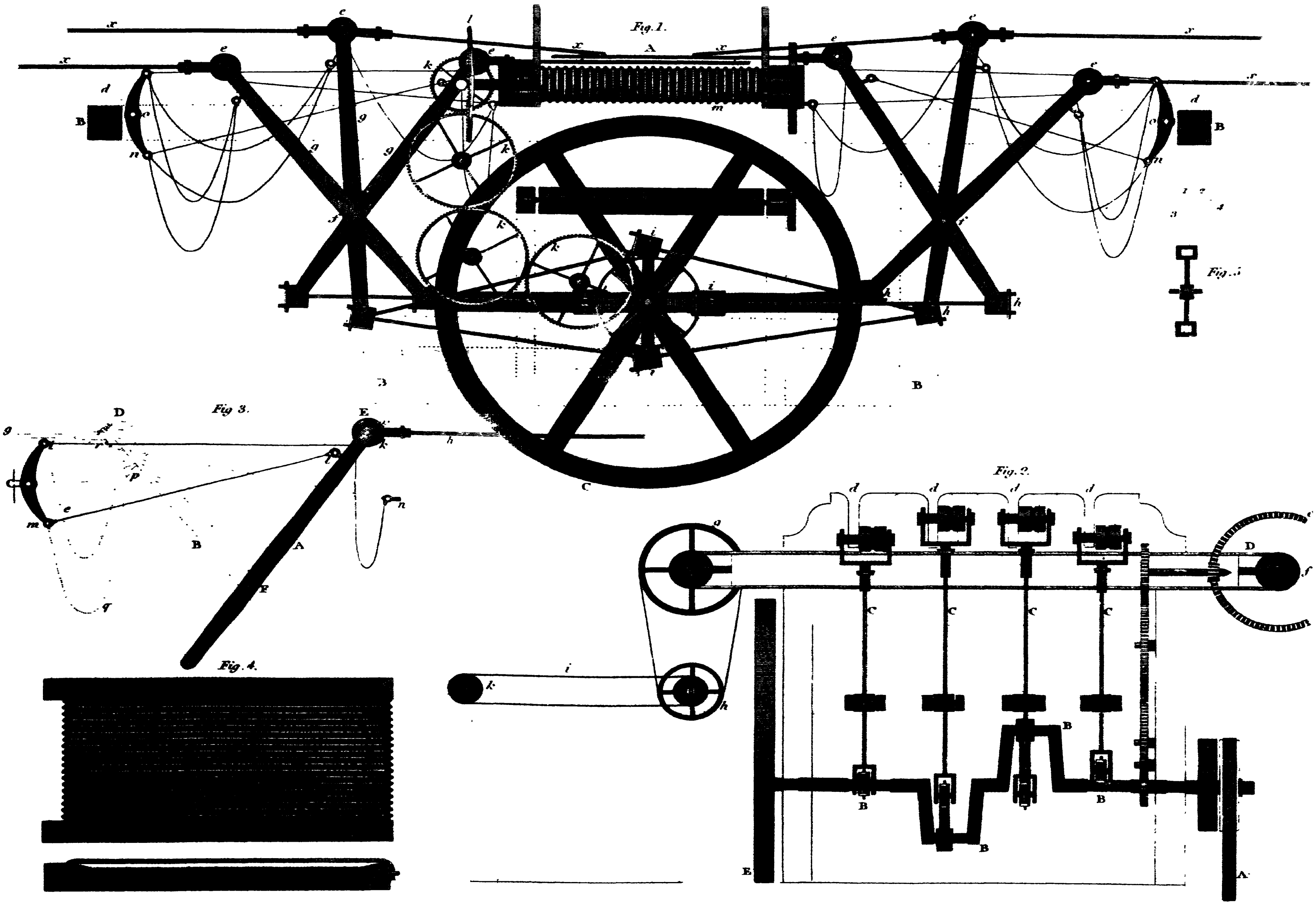
Drawn by Wm Thomson.

Published as the Act directs, 1808, by Longman, Hurst, Rees & Orme, Paternoster Row.

Engraved by Wilson Lowry.

COTTON MANUFACTURE.

BATTING MACHINE.



DEVILING.

Fig. 5.

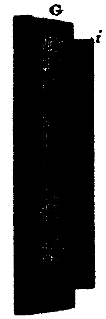


Fig. 3.

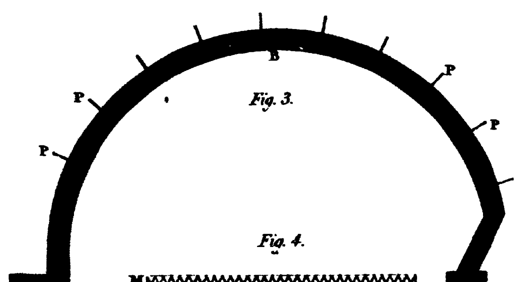
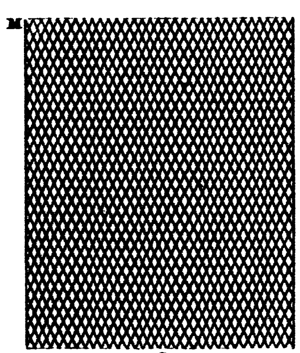


Fig. 4.



Plan.

Fig. 1.

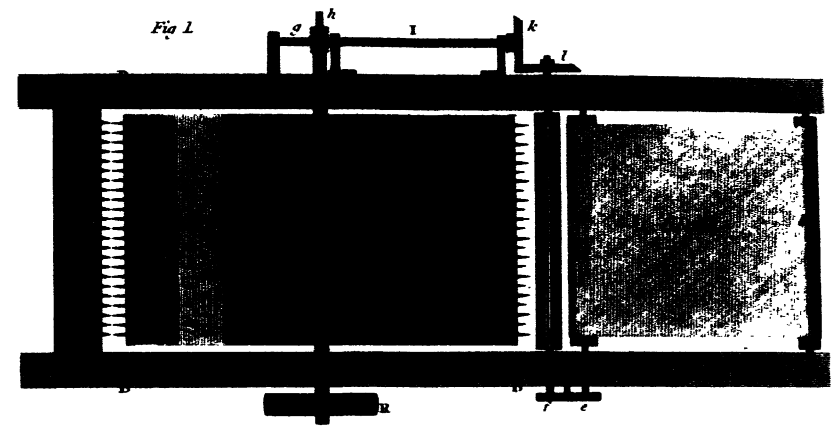
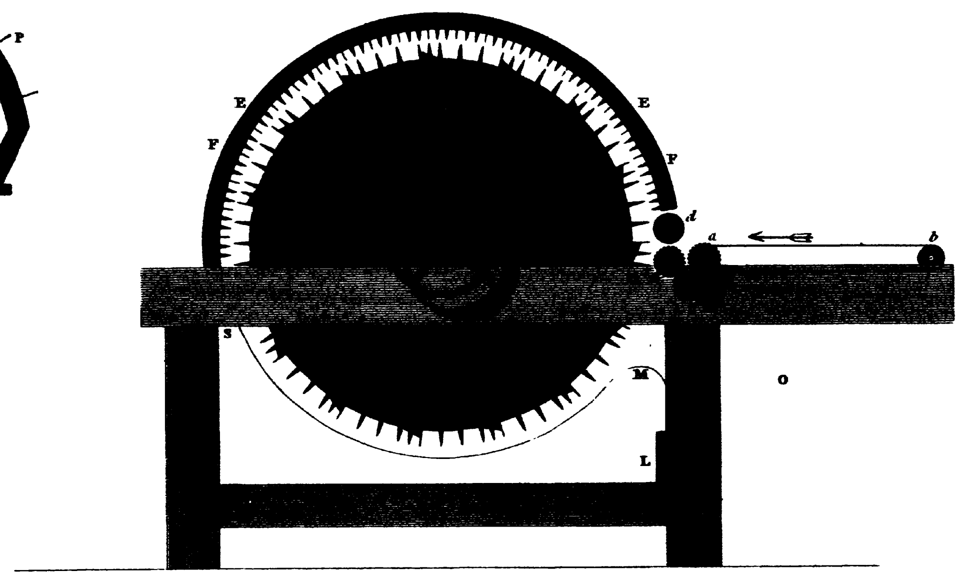


Fig. 2. Section.



Drawn by James Burton. Published as the Act directs, by Longman, Hurst, Rees, Orme & Brown, Paternoster Row. Engraved by Wilson Lowry.

COTTON MANUFACTURE.

CARDING.

Fig. 4.

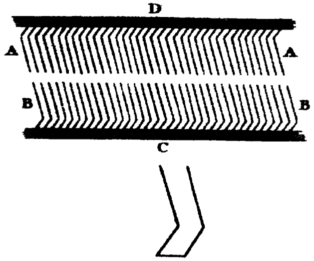


Fig 1. *Plan*

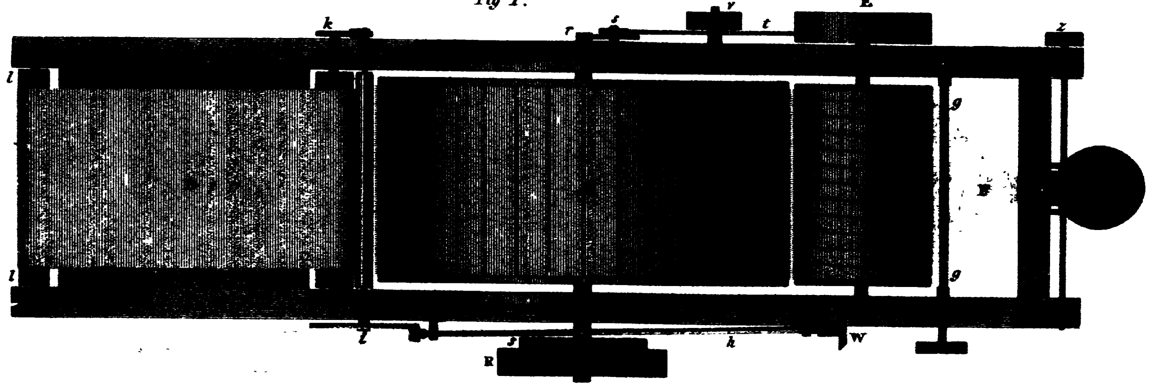


Fig. 3.

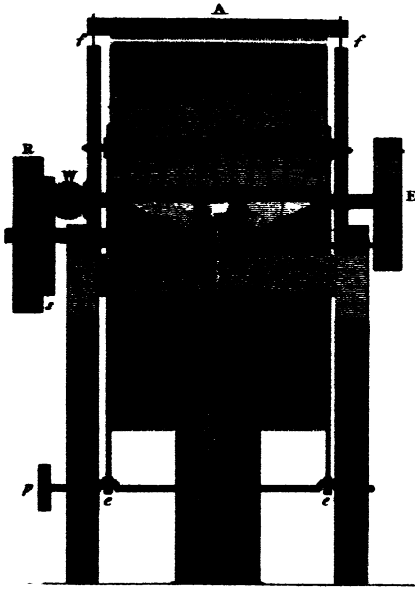
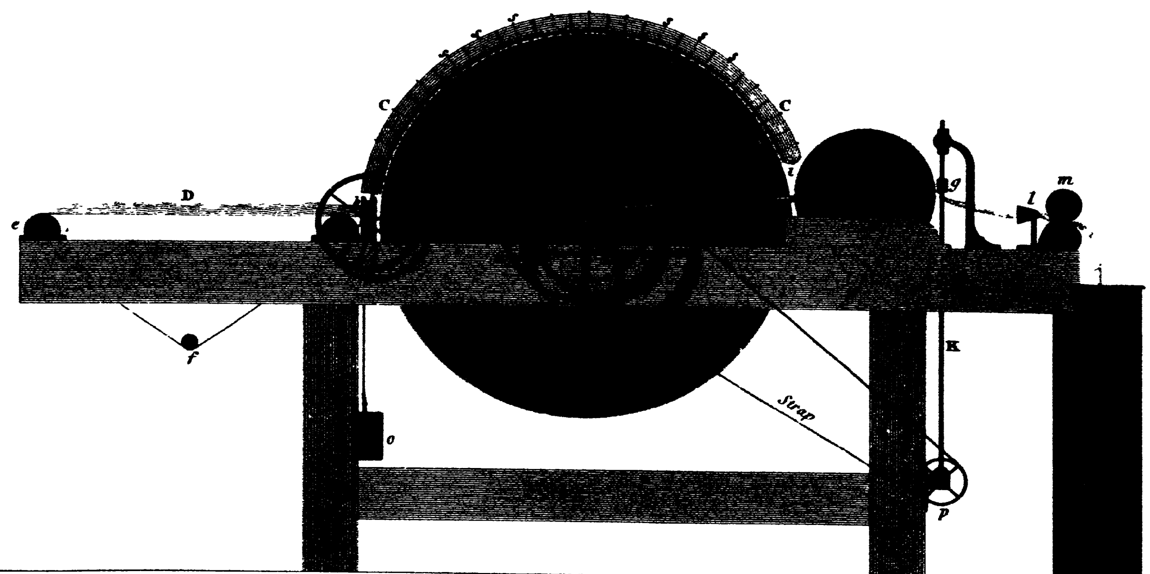


Fig 2. *Section*



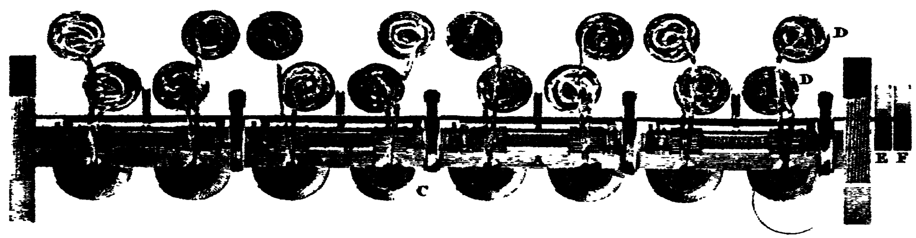
Drawn by James Barton.

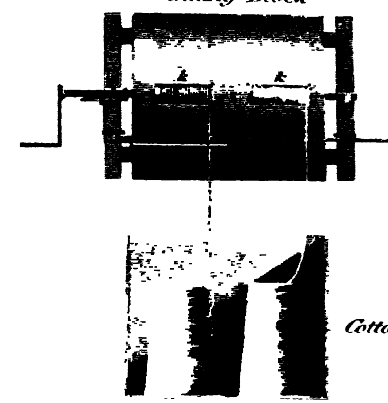
Published as the Act directs, 1809, by Longman, Hurst, Rees & Orme, Paternoster Row.

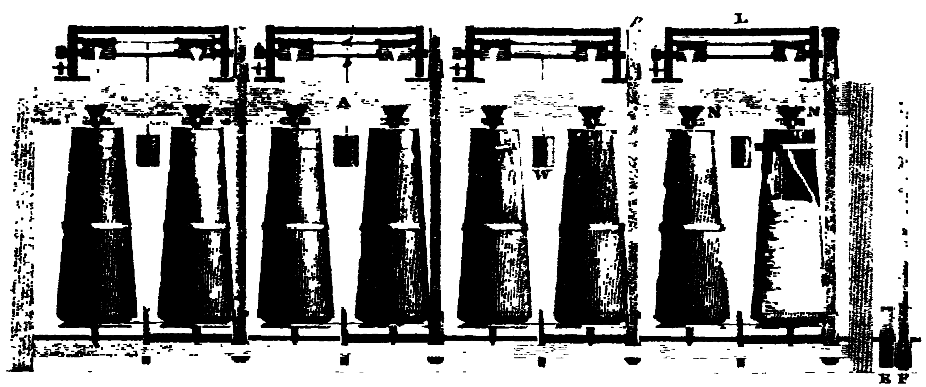
Engraved by Wilson Lowry

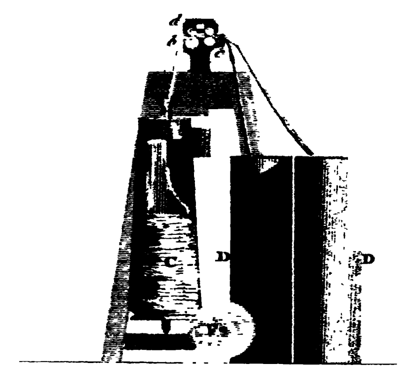
COTTON ANUFACTURE

'OF CAN FRAME.









A Roller beam.
b Front Roller.
c Back Roller.
d Top front Roller.
C Revolving Can.
W Roller weights.
P Can Pulley.
DD Back Cans.
E Driving Pulley.
F Loose Pulley.
NN Can Funnels.
L Clearer.
p Front roller Pulley.
k k Bobbins.

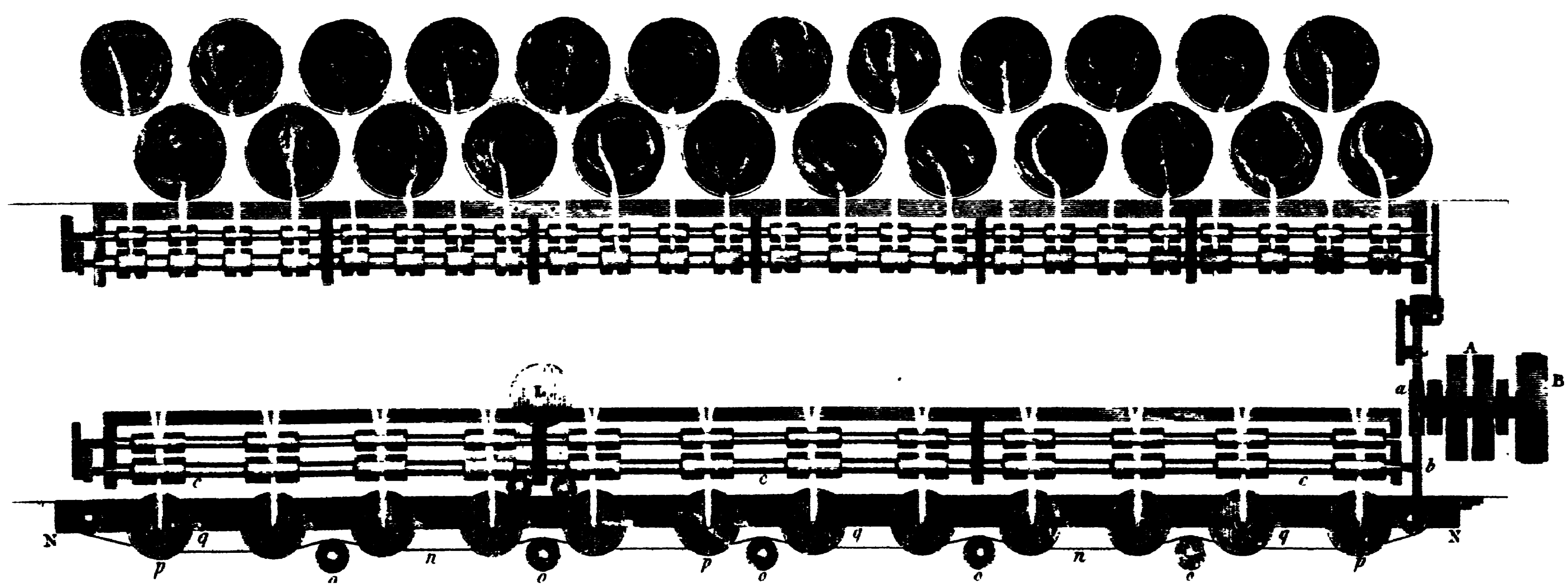
Published as the Act directs, 1810 by Longman, Hurst Rees & Orme, Paternoster Row.

Engraved by Wilson Lowry.

COTTON MANUFACTURE.

ROVING FRAME, Plate 1st

These cans contain the slivers brought from the Drawing frame.



Horizontal Plan of the Machine called Double Speeder.

COTTON MANUFACTURE.

ROVING FRAME termed *DOUBLE SPEEDER.*

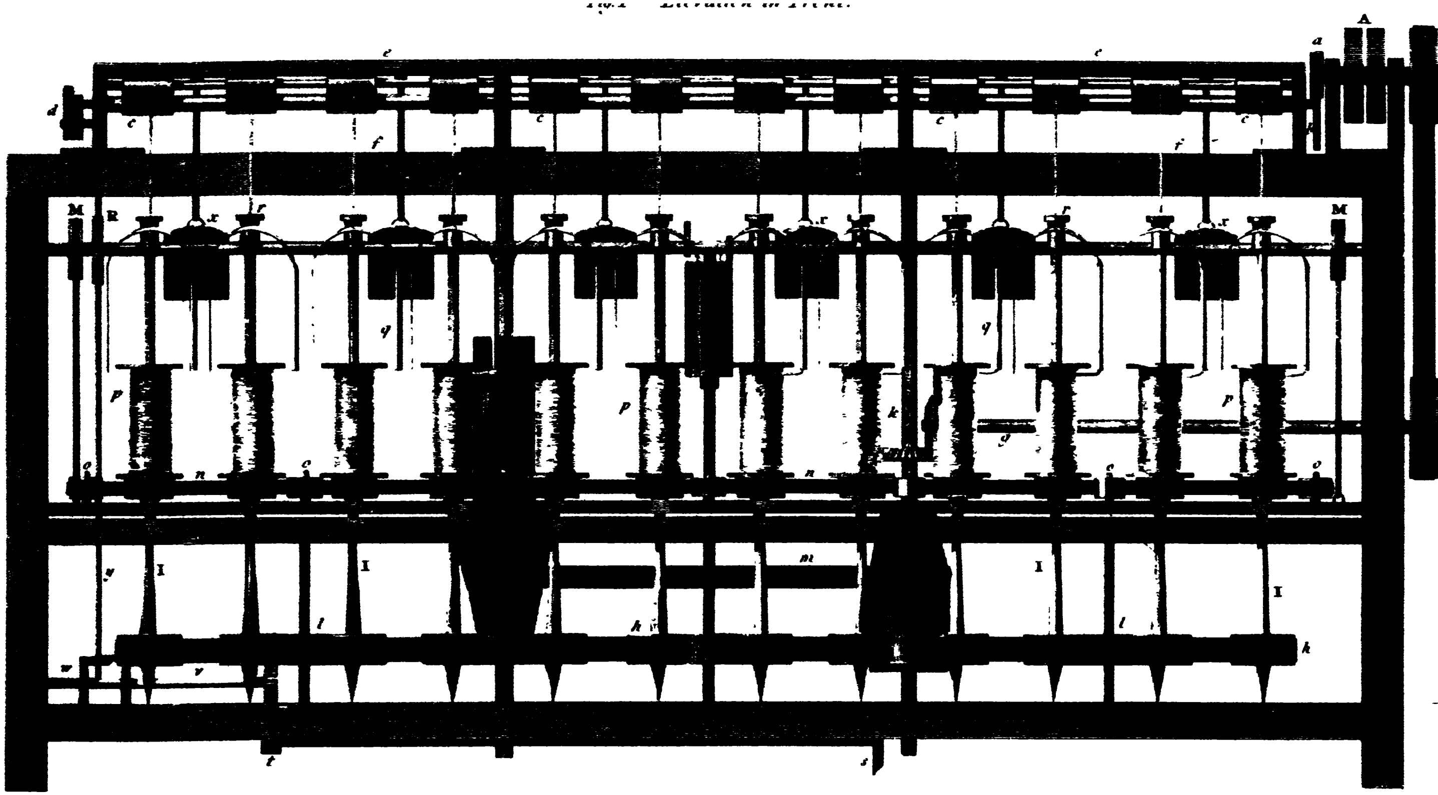
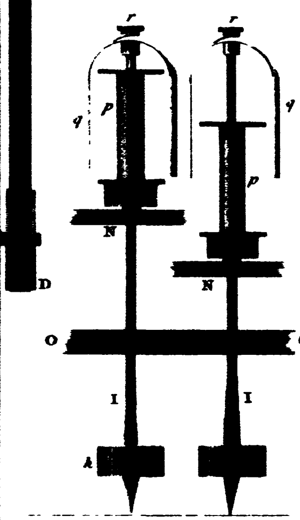


Fig. 2. & 3.



Barton del.

Published as the Act directs 18.. by Longman, Hurst, Rees, Orme and Brown, Paternoster Row London.

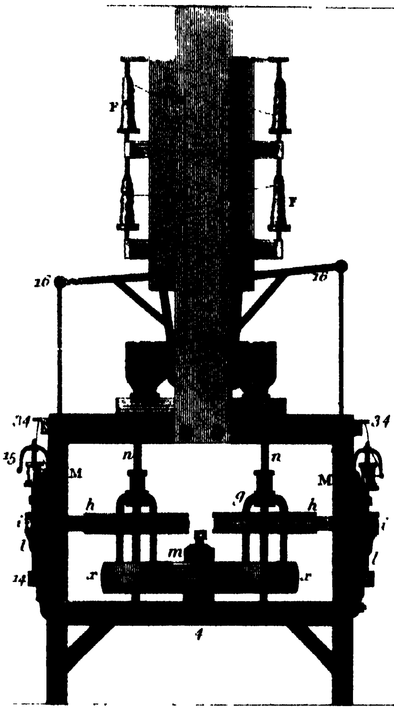
Engraved by Lowry.

COTTON MANUFACTURE.

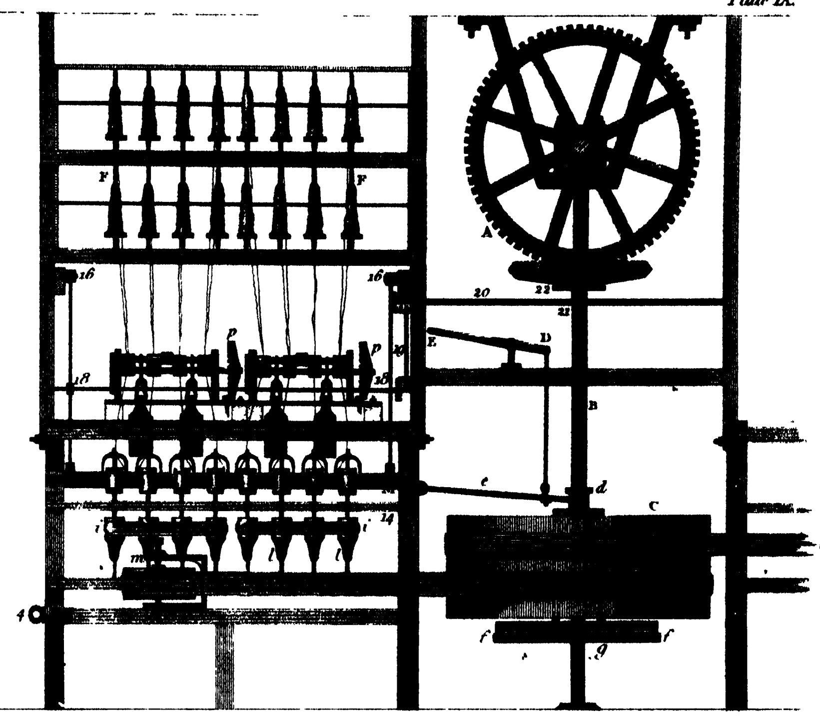
WATER SPINNING FRAME.

Plate IX.

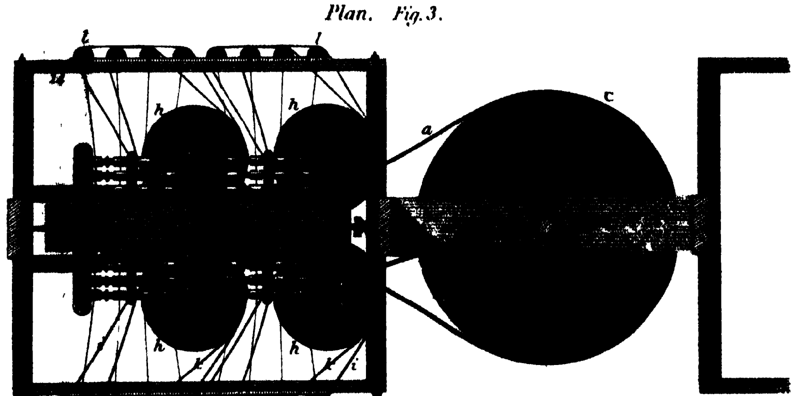
End View. Fig. 2.

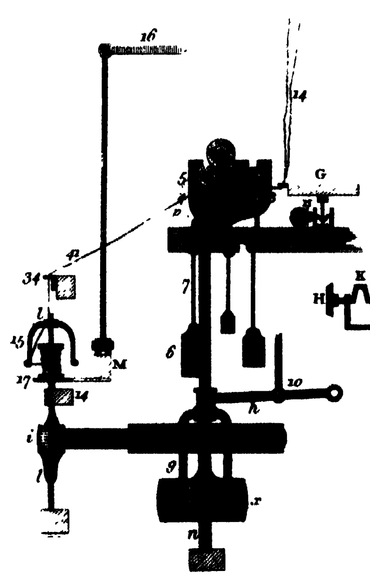


Elevation. Fig. 1.

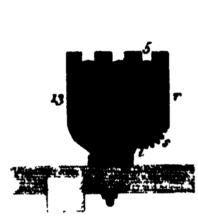


Plan. Fig. 3.

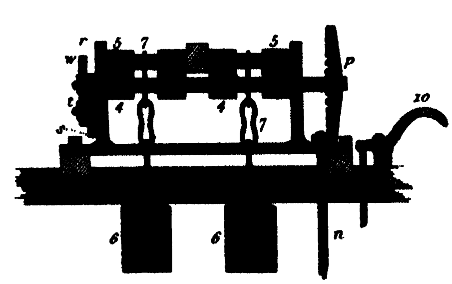




Spindle enlarged. Fig. 4.



End View. Fig. 6.



Elevation of Rollers. Fig. 5.

J. Farey, junr. delt. *W. Lowry sculpt.*

Published as the Act directs, 1813, by Longman, Hurst, Rees, Orme and Brown, Paternoster Row, London.

THROSTLE SPINNING FRAME.

Fig. 1.

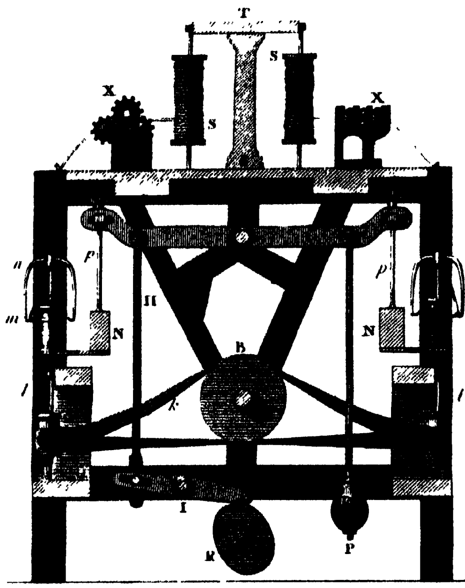


Fig.

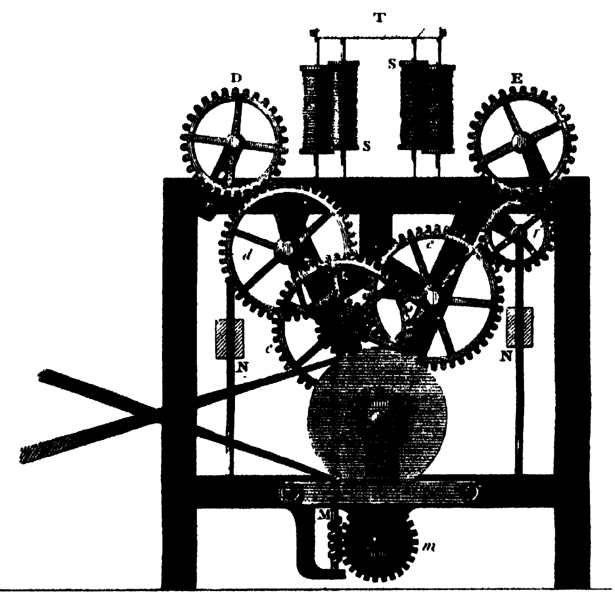
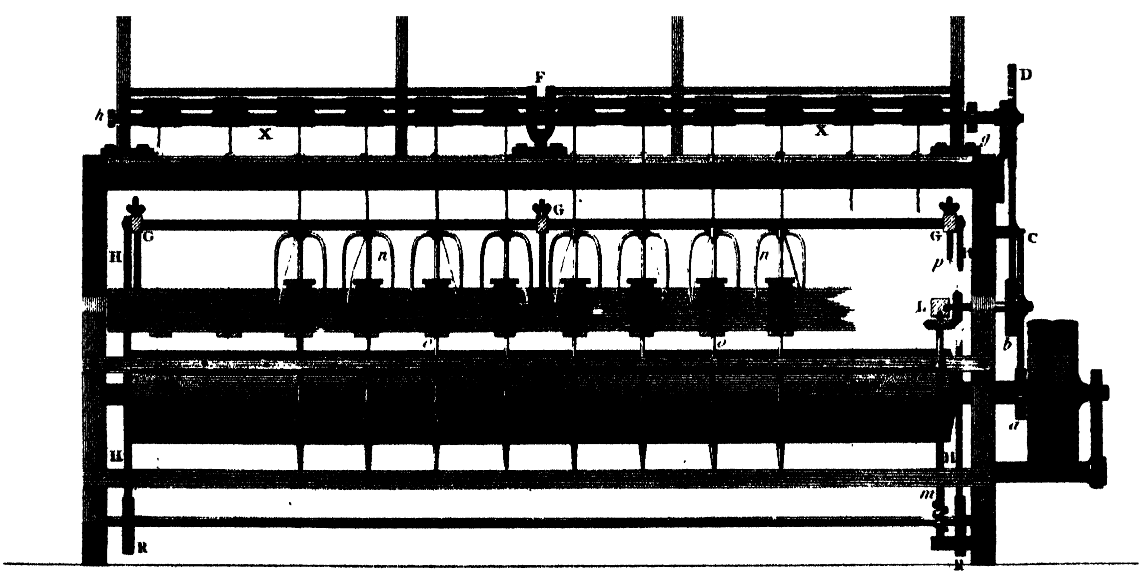


Fig. 3.

Elevation in Front.



Published as the Act directs, 1813, by Longman, Hurst, Rees, Orme and Brown, Paternoster Row, London.

Engraved by W. Lowry.

COTTON MANUFACTURE.

MULE SPINNING.

Fig. 1.

Fig. 2.

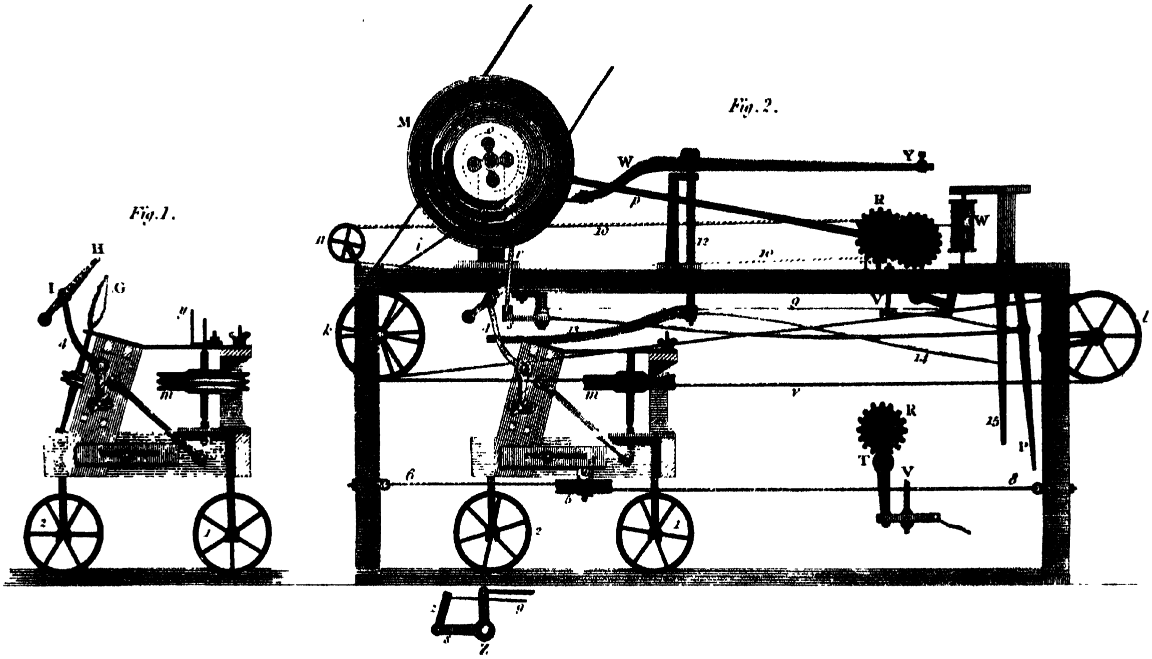


Fig. 3.

Elevation in Front.

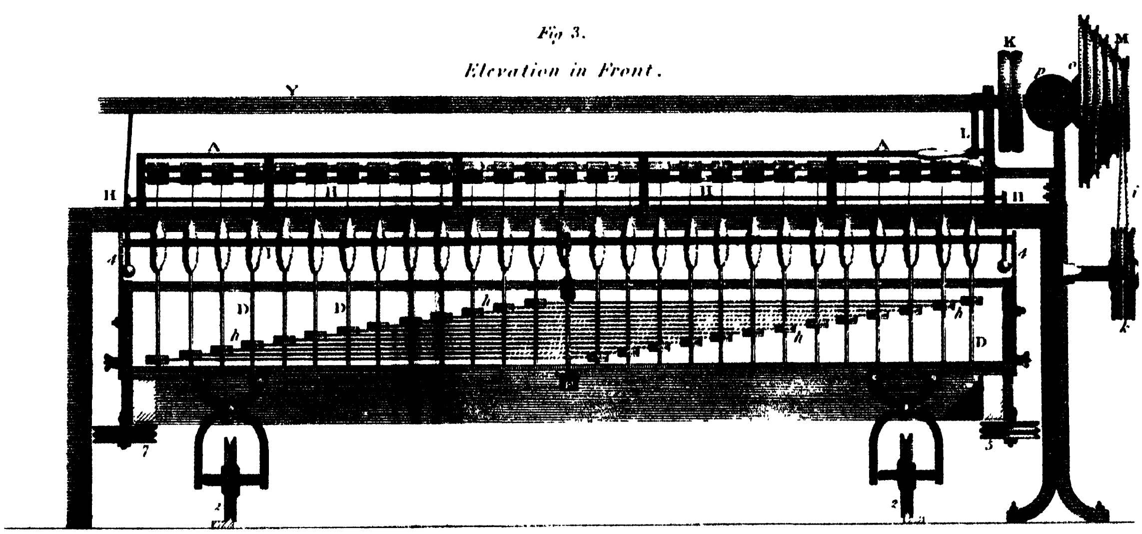


Fig. 4.

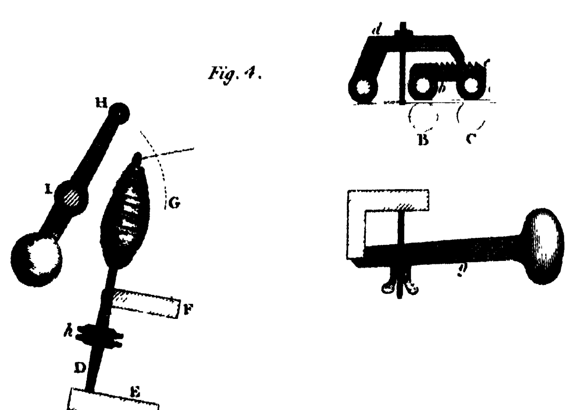
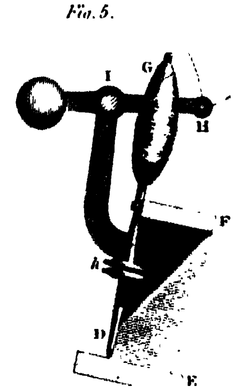


Fig. 5.



J. Farey del.

Published as the Act directs, 1814, by Longman Hurst Rees, Orme & Brown, Paternoster Row, London

W. Low

COTTON MANUFACTURE.

REELING.

Fig 1

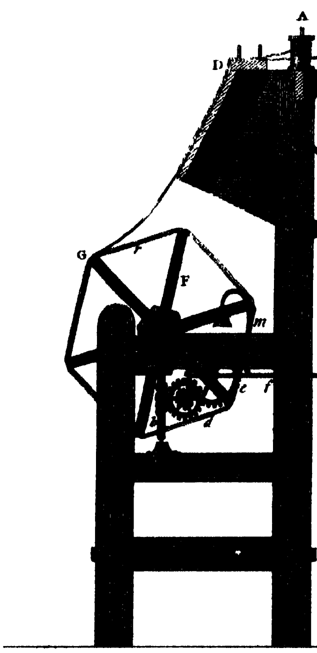
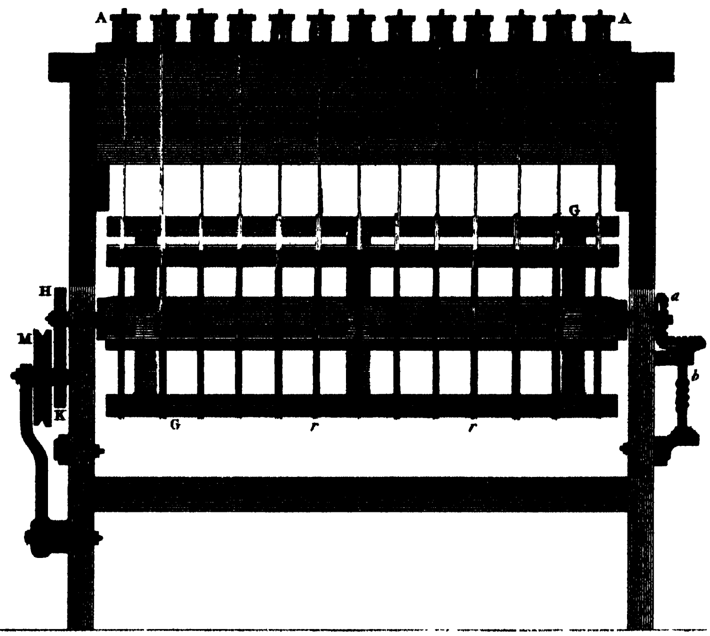


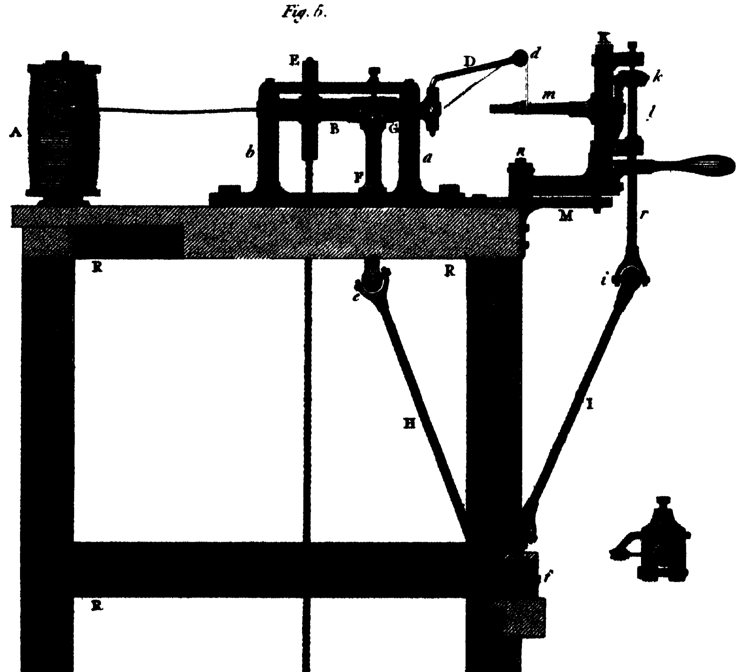
Fig. 2.



Machine for winding sewing cotton into Balls.

Fig. 3.

Fig. 6.



y Jun del.

Published as the Act directs, 1812, by Longman, Hurst, Rees, Orme and Brown, Paternoster Row, London.

Fig. 2.

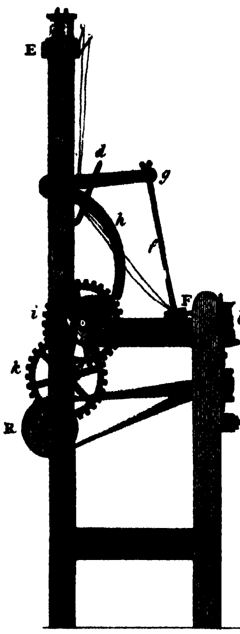
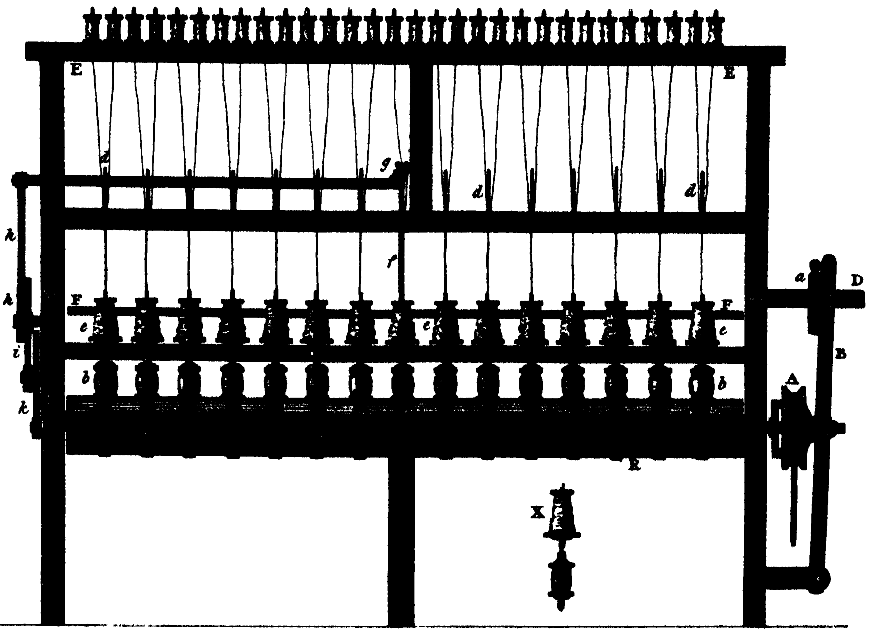
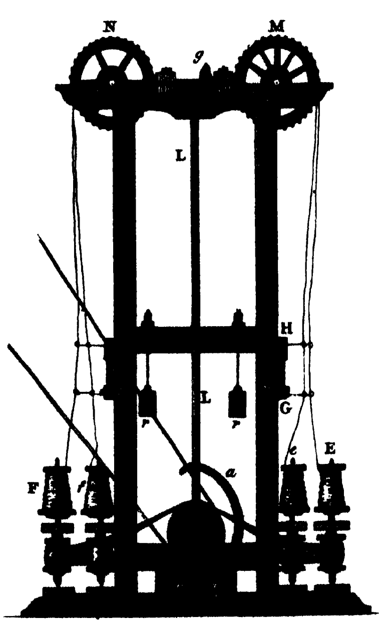


Fig. 1. DOUBLING MACHINE.

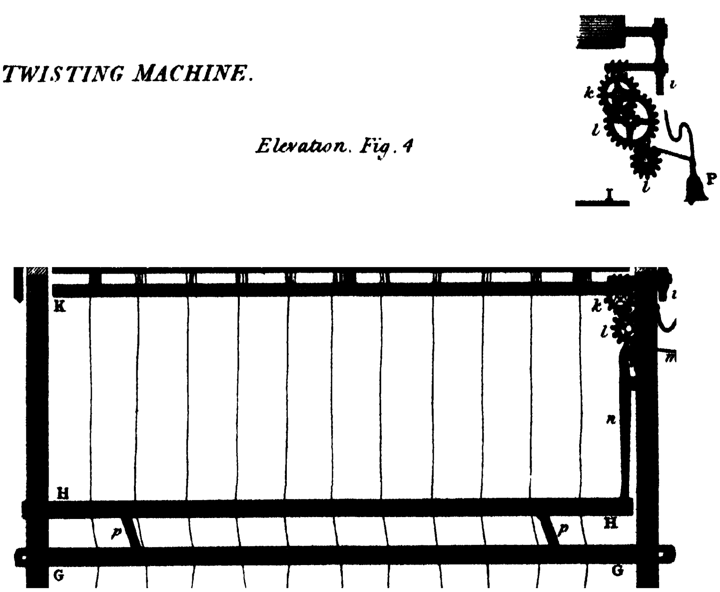


TWISTING MACHINE.

End View. Fig. 3.



Elevation. Fig. 4



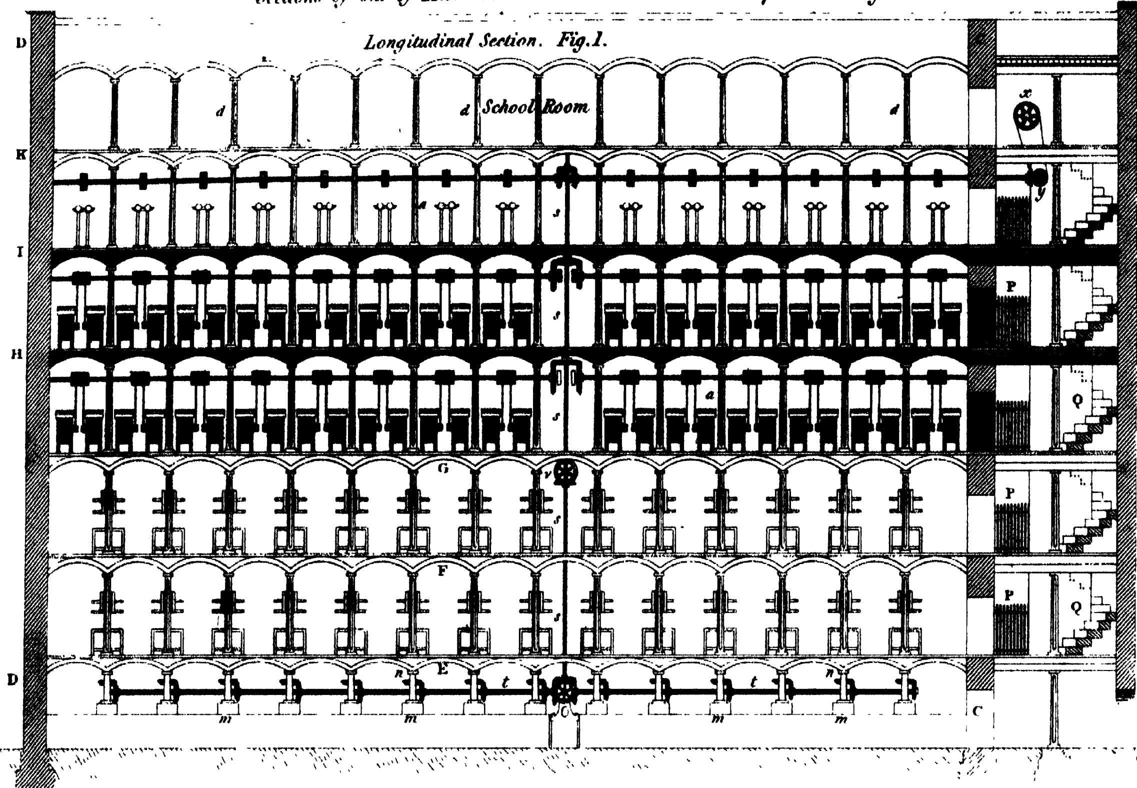
J. Farey Jun. del

Published as the Act directs, 1814, by Longman, Hurst, Rees, Orme & Brown, Paternoster Row London.

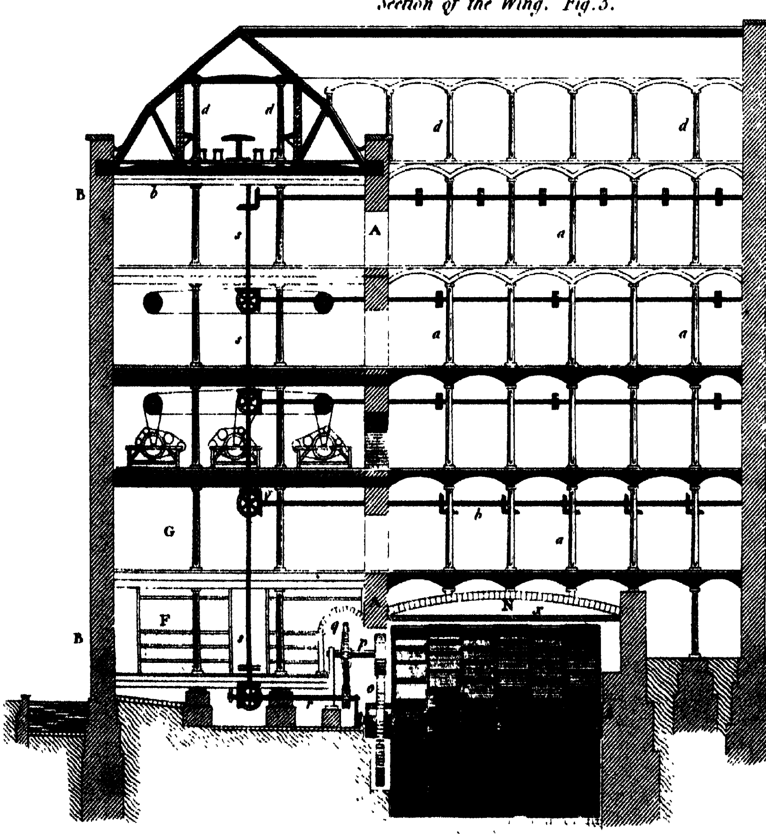
COTTON MANUFACTURE.

PLATE XIV.

Sections of one of Mess.rs Strutt's COTTON MILLS at Belper in Derbyshire.



Longitudinal Section. Fig. 1.



Section of the Wing. Fig. 3.

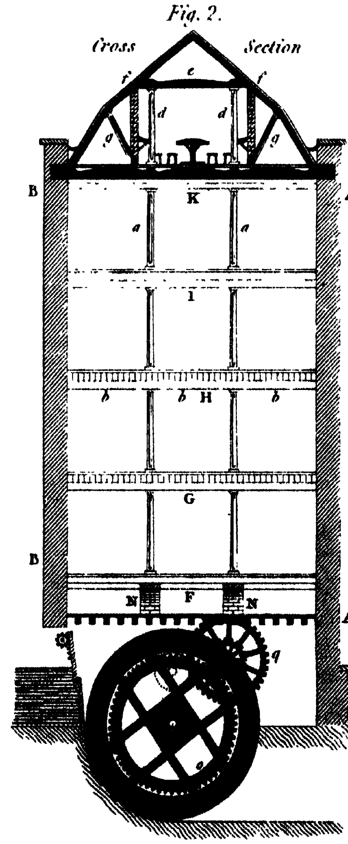


Fig. 2. Cross Section

J. Farey Jun. del.

Published as the Act directs, 1811, by Longman, Hurst, Rees, Orme & Brown, Paternoster Row, London.

W. Lowry sculp.

Crane

Crane, in *Hydraulics*, a popular name for a *Siphon;* which see.

Crane, in *Mechanics*, a machine used in *Building* and in *Commerce*, for raising large stones, and other weights, to certain heights, or lowering them to certain depths.

M. Perrault, in his notes on Vitruvius, makes the crane the same with the *corvus*, or raven, of the ancients.

The modern crane consists of several members, or pieces, the principal being a strong perpendicular beam, or arbor, firmly fixed in the ground, and sustained by eight arms, coming from the extremities of four pieces of wood laid across, through the middle of which the foot of the beam passes. About the middle of the arbor the arms meet, and are mortised into it: its top ends in an iron pivot, on which is borne a transverse piece, advancing out to a good distance in manner of a crane's neck; whence its name. The middle and extremity of this are again sustained by arms from the middle of the arbor: and over it comes a rope, or cable, to one end of which the weight is fixed; the other is wound round the spindle of a wheel, which turned, draws the rope, and that heaves up the weight; to be afterwards applied to any side or quarter, by the mobility of the transverse piece on the pivot.

There are several improvements of this useful machine mentioned in Desaguliers's Experim. Philos. p. 178, *seq.* particularly how to prevent the inconveniences arising from sudden jerks, as well as to increase its force by using a double axis *in peritrochio*, and two handles.

The crane is of two kinds; in the first kind, called the *rat-tailed crane*, the whole machine, with the load, turns upon a strong axis: in the second kind, the gibbet alone moves on its axis. We shall refer to Desaguliers, *ubi supra*, for a particular account of different cranes, and recite improvements in the construction of them: beginning with a description of one, in which most of them are combined, invented by the late Mr. Padmore of Bristol. This consists of wheels, axles, pulleys, ropes, and a gib or gibbet. *Plate* XVIII. *Mechanics*, *fig.* 2. When the rope, H, is hooked to the weight K, a man turns the winch A, on the axis of which is the trundle B, which turns the wheel C, on whose axis, D, is the trundle E, which turns the wheel F, with its upright axis G, on which the great rope, H H, winds as the wheel turns; and going over a pulley, I, at the end of the arm, *d*, of the gib *c c d e*, it draws up the heavy burden K; which, being raised to a proper height, as from a ship to the quay, is then brought over the quay by pulling the wheel, Z, round by the handles *z*, *z*, which turns the gib by means of the half wheel, *b*, fixed on the gib-post *c c*, and the strong pinion, *a*, fixed on the axis of the wheel Z. This wheel gives the man that turns it an absolute command over the gib, so as to prevent it from taking any unlucky swing, such as often happens when it is only guided by a rope tied to its arm *d*; and people are frequently hurt, sometimes killed, by such accidents.

The great rope goes between two upright rollers *i* and *k*, which turn upon gudgeons in the fixed beams *f* and *g*; and as the gib is turned towards either side, the rope bends upon the roller next that side. Were it not for these rollers, the gib would be quite unmanageable; for the moment it were turned ever so little towards any side, the weight, K, would begin to descend, because the rope would be shortened between the pulley I, and axis G; and so the gib would be pulled violently to that side, and either be broke to pieces, or break every thing that came in its way. These rollers must be placed so, that the sides of them, round which the rope bends, may keep the middle of the bended part directly even with the centre of the hole in which the upper gudgeon of the gib turns in the beam *f*. The truer these rollers are placed, the easier the gib is managed, and the less apt to swing either way by the force of the weight K.

A ratchet-wheel, Q, is fixed upon the axis D, near the trundle E; and into this wheel falls the catch or click R. This hinders the machine from running back by the weight of the burden K, if the man who raises it should happen to be careless, and so leave off working at the winch, A, sooner than he ought to do.

When the burden, K, is raised to its proper height from the ship, and brought over the quay by turning the gib about, it is let down gently upon the quay, or into a cart standing thereon, in the following manner. A man takes hold of the rope *t t*, (which goes over the pulley *v*, and is tied to a hook at S, in the catch R,) and so disengages the catch from the ratchet-wheel Q; and then, the man at the winch, A, turns it backward, and lets down the weight K. But if the weight pulls too hard against this man, another lays hold of the handle V, and by pulling it downward, draws the gripe, U, close to the wheel Y, which, by rubbing hard against the gripe, hinders the too quick descent of the weight; and not only so, but even stops it at any time,

if required. By this means, heavy goods may be either raised or let down at pleasure, without any danger of hurting the men who work the engine.

When part of the goods is craned up, and the rope is to be let down for more, the catch, R, is first disengaged from the ratchet-wheel Q, by pulling the cord *t*; then the handle, *q*, is turned half round backward, which, by the crank, *n n*, in the piece *o*, pulls down the frame, *k*, between the guides *m* and *m*, (in which it slides in a groove,) and so disengages the trundle, B, from the wheel C: and then, the heavy hook, *β*, at the end of the rope, H, descends by its own weight, and turns back the great wheel, F, with its trundle, E, and the wheel C; and this last wheel acts like a fly against the wheel, F, and hook *β*; and so hinders it from going down too quick; whilst the weight, X, keeps up the gripe, U, from rubbing against the wheel Y, by means of a cord going from the weight, over the pulley, *w*, to the hook, W, in the gripe; so that the gripe never touches the wheel, unless it be pulled down by the handle V.

When the crane is to be set at work again, for drawing up another burden, the handle, *q*, is turned half round forwards; which, by the crank *n n*, raises up the frame *h*, and causes the trundle, B, to lay hold of the wheel C; and then, by turning the winch A, the burden of goods, K, is drawn up as before.

The crank, *n n*, turns pretty stiff in the mortise near *o*, and stops against the farther end of it when it has got just a little beyond the perpendicular; so that it can never come back of itself: and therefore, the trundle, B, can never come away from the wheel C, until the handle, *q*, be turned half round backward.

The great rope runs upon rollers in the lever L M, which keep it from bending between the axle at G and the pulley I. This lever turns upon the axis, N, by means of the weight O, which is just sufficient to keep its end, L, up to the rope; so that, as the great axle turns, and the rope coils round it, the lever rises with the rope, and prevents the coilings from going over one another.

The power of this crane may be estimated thus: suppose the trundle, B, to have 13 staves or rounds, and the wheel, C, to have 78 spur cogs; the trundle, E, to have 14 staves, and the wheel, F, 56 cogs. Then, by multiplying the staves of the trundles, 13 and 14, into one another, their product will be 182; and by multiplying the cogs of the wheels, 78 and 56, into one another, their product will be 4368, and dividing 4368 by 182, the quotient will be 24; which shews that the winch, A, makes 24 turns for one turn of the wheel, F, and its axle, G, on which the great rope or chain, H I H, winds. So that, if the length or radius of the winch, A, were only equal to half the diameter of the great axle G, added to half the thickness of the rope H, the power of the crane would be as 24 to 1: but the radius of the winch being double the above length, it doubles the said power, and so makes it as 48 to 1: in which case, a man may raise 48 times as much weight by this engine as he could do by his natural strength without it, making proper allowance for the friction of the working parts. Two men may work at once, by having another winch on the opposite end of the axis of the trundle under B; and this would make the power double.

If this power be thought greater than what may be generally wanted, the wheels may be made with fewer cogs in proportion to the staves in the trundles; and so the power may be of any degree that is judged to be requisite. But if the weight be so great as will require yet more power to raise it (suppose a double quantity), then the rope, H, may be put under a moveable pulley, as *δ*, and the end of it tied to a hook in the gib at *ε*; which will give a double power to the machine, and so raise a double weight hooked to the block of the moveable pulley.

When only small burdens are to be raised, this may be quickly done by men pushing the axle, G, round by the handspikes *y*, *y*, *y*, *y*; having first disengaged the trundle, B, from the wheel C. and then, this wheel will only act as a fly upon the wheel F; and the catch, R, will prevent its running back, if the men should inadvertently leave off pushing before the burden be unhooked from *β*.

Lastly, when very heavy burdens are to be raised, which might endanger the breaking of the cogs in the wheel F: their force against these cogs may be much abated by men pushing round the handspokes *y*, *y*, *y*, *y*, whilst the man at A turns the winch. Ferguson's Lectures on Select Subjects, 4to. p. 52, &c.

If the axis, G G, be placed horizontally, and instead of the wheel, F, a larger wheel be fixed to it, which may be turned by men walking in it, we shall have another kind of crane; the rope will coil round the axle as the wheel turns, and the gib-work is the same as in the other sort of crane. Mr. Padmore contrived to prevent the danger attending the use of this construction, by putting cogs all round the outside of the wheel, and applying a trundle to turn it; by which addition the power is increased in the proportion of the number of cogs to the number of staves in the trundle: and in order to hinder its running back by the force of the weight, should the men within it slip, or leave off walking, he added a ratchet-wheel to the axis of the trundle, like that already described. Two winches may also be fixed to the ends of the axle, by working which the men in the wheel would be much assisted. On the axle of the trundle he likewise fixed a gripe-wheel, such as has been already described, by means of which heavy burdens may be let down without the least danger.

Mr. Ferguson has contrived and described a new and safe crane, with four different powers adapted to different weights; for which he received a reward of 50*l.* from the Society for the encouragement of arts, &c. In this crane (see *Plate* XVIII. *Mechanics*, *fig.* 3.) A represents the great wheel, and B its axle, on which the rope, C, winds. This rope goes over a pulley, D, in the end of the arm of the gib E, and draws up the weight F, as the winch, G, is turned round. H is the largest trundle, I the next, and K is the axis of the smallest trundle, which is supposed to be hid from view by the upright supporter L. A trundle, M, is turned by the great wheel, and on the axis of this trundle is fixed the ratchet-wheel N, into the teeth of which the catch, O, falls. P is the lever, from which goes a rope, Q Q, over a pulley, R, to the catch; one end of the rope being fixed to the lever, and the other end to the catch. S is an elastic bar of wood, one end of which is screwed to the floor: and, from the other end goes a rope (out of sight in the figure) to the farther end of the lever, beyond the pin or axis on which it turns in the upright supporter T. The use of this bar is to keep up the lever from rubbing against the edge of the wheel U, and to let the catch keep in the teeth of the ratchet-wheel: but a weight hung to the farther end of the lever, would do full as well as the elastic bar and rope.

When the lever is pulled down, it lifts the catch out of the ratchet-wheel, by means of the rope Q Q, and gives the weight, F, liberty to descend: but if the lever, P, be pulled a little farther down than what is sufficient to lift the catch, O, out of the ratchet-wheel N, it will rub against the edge of the wheel, U, and thereby hinder the too quick descent of the weight; and will quite stop the weight, if pulled hard. And if the man who pulls the lever should happen inad-

vertently to let it go; the elastic bar will suddenly pull it up, and the catch will fall down and stop the machine.

W, W, are two upright rollers, above the axis or upper gudgeon of the gib E: their use is to let the rope, C, bend upon them, as the gib is turned to either side, in order to bring the weight over the place where it is intended to be let down: which rollers ought to be so placed, that if the rope, C, be stretched close by their outmost sides, the half thickness of the rope may be perpendicularly over the centre of the upper gudgeon of the gib; for then the length of the rope between the pulley in the gib and the axle of the great wheel, will be always the same, in all positions of the gib, and the gib will remain in any position to which it is turned.

The powers of this machine may be easily calculated: the horizontal-wheel has ninety-six cogs, the largest trundle twenty-four staves, the next largest has twelve, and the smallest has six. So that the largest trundle makes four revolutions for one revolution of the wheel; the next makes eight; and the smallest makes sixteen. When a winch is occasionally put upon the axis of either of these trundles for turning it, the handle of the winch describes a circle in every revolution equal to twice the circumference of the axle of the wheel; and therefore the length of the winch doubles the power gained by each trundle. So that if the winch be applied to the axle of the largest trundle and turned four times round, the wheel and axle will be turned once round, and the power will move through eight times as much space as the weight rises through: in which case the power will be to the weight as eight to one; *i. e.* a man may raise (allowing for friction) eight times as much weight by the crane, as he might by his natural strength without it. If the second trundle be used, the proportion of the power to the weight will be as sixteen to one; and with the smallest trundle, as thirty-two to one. The power may again be doubled by drawing up the weight by one of the parts of a double rope, going under a pulley in the moveable block, which is hooked to the weight below the arm of the gib; for then the power will be as sixty-four to one: and by increasing the number of pullies, the power will be proportionably increased. See Supplement to Ferguson's Lectures, p. 3, &c. or Phil. Trans. vol. liv. art. 3. p. 24.

An improved crane for wharfs has lately been invented by Mr. Robert Hall of Basford, near Nottingham, who was rewarded with 40 guineas by the Society of Arts. The invention chiefly consists in expanding a set of bars parallel to the axis of a crane, by means of which the velocity of the ropes in raising weights may be diminished or increased, in proportion to the load which is to be raised. An engraving and description of this crane may be seen in the 12th volume of the Transactions of the Society, p. 283, &c. We have already observed under the article CAPSTAN, that the capstan with a compound barrel, consisting of two cylinders of different radii, may be converted into a crane or windlas for raising weights. Such a crane is evidently superior to those in common use, with the additional advantage of allowing the weight to stop in any part of its progress, without the aid of a ratchet-wheel and catch, as the two parts of the rope pull on contrary sides of the barrel. The rope, indeed, which coils round the larger part of the barrel, acts with a longer lever, and consequently with greater force than the other; but as this excess of force is not sufficient to overcome the friction of the gudgeons, the weight remains stationary in any part of its path. A crane of this kind was erected, in 1797, at Bordenton in New Jersey, by Mr. M'Kean, for the purpose of raising logs of wood to the frame of a saw-mill, 10 feet distant from the ground.

We are happy here to lay before the public a design for a crane, by the late Mr. John Smeaton, through the liberality of sir Joseph Banks, who kindly permitted our draughtsman to make a reduced copy of the original drawing, which he purchased, with many others, since the demise of Mr. Smeaton. The machine was erected at the wool quay custom-house, London, in 1789. *Fig.* 2, (*Plate* XIX. *Mechanics*) is a plan of it; *fig.* 3, an elevation; and *fig.* 1, a section of the barrel: the same letters of reference are used in each figure. A is the barrel upon which the chain is wound; it has seven turns of a spiral groove cut upon it, to receive the lower half of the links of the chain, as will be clearly understood from *fig.* 3; *a, a, fig.* 2, are two of four handles (the others not being shewn) screwed to the end of the barrel by long bolts going through its whole length, as shewn in *fig.* 1; the other ends of the same bolts attach to the barrel, a wheel, B, with hooked teeth. The barrel, with its wheel, B, and handles, has a metal bush driven into its centre, and well fitted to a nicely turned arbor, *b*, in the section, *fig.* 1, so as to turn upon it freely without shake. This arbor has a shoulder, C, upon it truly turned, against which the great wheel, D, fits, and is held fast to it by four screws (*fig.* 2.); the great wheel, D, and barrel are connected together by means of two clicks, *d, d,* (*fig.* 3.) turning on pins made fast to the wheel, and pressed by springs into the teeth of the ratchet-wheel B. The great wheel, D, has 96 teeth, and is turned by a lantern, E, of 11 staves, on the arbor *f*. F is a fly-wheel fitted on the same arbor by a shoulder, in the same manner as the great wheel. G is a broad wooden wheel on the arbor, *f*, encompassed half round by a brake, *g*, formed of four pieces; it is brought to touch the wheel by a foot lever, H, *fig.* 3. and a weight at the opposite end of the lever lifts it off the wheel when not in use. I is a ratchet-wheel, and *i* the click to prevent the crane running back; K, K, are the winches by which it is turned. The ratchet and click on the barrel are used when the crane is lowering goods, and the chain is to be drawn up with any work; the workmen then turn the barrel by the four handspikes, *a, a,* the sloping sides of the ratchet-wheel lifting up the clicks, *d, d,* and passing by, without the labour and loss of time of turning the wheels; and likewise, when the crane is used for raising goods, and the chain is to be let down without any load, the barrel must be turned back a small space, and the clicks disengaged, by pushing one of their tails, *n* or *n*, for which purpose they are connected to move together by a small rod *o*; the barrel then runs down by the weight of the chain, and if that is not sufficient, the workman assists it by the handspikes, *a, a.* The contrivance of the grooved barrel is of very great use, as without it the chain lies in such a manner that the action of the load tends to twist open the links laterally. Mr. Gilbert Gilpin of Shifnal was rewarded by the Society of Arts, in 1803, for the same invention, without perhaps knowing Mr. Smeaton had applied it before him. As he has very well explained the advantages of this construction, we shall make use of his own words from the Transactions of the Society, vol. ii. p. 3.

Every chain formed of oval links has a twist in itself, arising from a depression given by the hammer to each link in the welding: the twist may be seen by holding the piece of the chain by one end, and viewing the links edgeways as it hangs down; and this circumstance, so trifling in appearance, is not so in its effects; and it has in consequence a perpetual tendency (even when reefed perfectly straight in pullies, and on the barrels of cranes) to assume a spiral form, which a plain cylindrical barrel, and the common pullies with semicircular grooves, are not in the least calculated to prevent. Hence the alternate links of the chain, in coiling round a

barrel, or working over pullies, form obtufe angles in affuming the fpiral form, bearing upon the lower parts of their circumferences, and forming as it were two levers, which wrench open and crufh each other in proportion to the weight fufpended, as well as prevent the freedom of motion in the links themfelves, and thereby load the chain with additional friction.

A ftill greater obftruction to the uniformity of its motion, is the tendency which the chain has to make a double coil, as it approaches the middle of the barrel, and croffes its centre, and that of the pullies at right angles, by means of which the chain is frequently broken by the fudden jerk, caufed by the upper coil flipping off the undermoft.

It is to thefe caufes that all the accidents that occur to workmen and machinery, from the failure of chains, may be attributed, (bad iron excepted,) and which form the fole objection to their becoming a general fubftitute for ropes.

As a preventive to thefe evils, fays this writer, I have grooves caft in iron pullies, of fufficient dimenfions to receive the lower circumferences of the links of the chain, which work vertically: thofe which work horizontally and form the gudgeon part of the chain (if we may be allowed the expreffion,) bearing up on each fide of the grooves.

The barrels are alfo of caft iron, with fpiral grooves of the fame dimenfions, at fuch diftance from each other as to admit the chain to bed without the danger of a double coil; by thefe means the links are retained at right angles with each other, the only pofition for free and uniform motion.

The links of the chains are made as fhort as poffible, for the purpofe of increafing their flexibility, and they are reefed perfectly free from twift in the pullies and on the barrels, for the fame reafon.

When applied in block, the grooves in the pullies prevent the different falls of the chain from coming in contact, and render plates betwem them (as in the common way) totally unneceffary; the pullies are in confequence brought clofer together, the angle of the fall from block to block confiderably diminifhed, and the friction againft the plates entirely avoided. Brafs guards, with grooves oppofite to thofe in the pullies, are rivetted to the blocks, to prevent the chain getting out of its birth from any accidental circumftance. This method of working chains I firft put in practice for Meffrs. T. W. and B. Botfield, at their works, in July 1803; and it is applied in the working of cranes capable of purchafing from ten to fifteen tons; in the working of the governor balls of fteam engines conftructed by Meffrs. Boulton and Watt, and in the raifing of coal and ore from the mines, for which purpofes ropes had before been folely ufed at this manufactory. In all cafes it has performed with the utmoft fafety, uniformity, and flexibility; fo much fo, that the prejudices of our workmen againft chains are entirely done away, and they hoift the heavieft articles with more eafe, and as great confidence of fafety, as they would with the beft ropes.

The fame method is applicable, at a trifling expence, to all machines at prefent worked by ropes, or by chains, in the ufual way: and all the common chains now in ufe, may be applied to it with equal facility.

With a view of afcertaining the relative flexibility of ropes and chains, I wedged an iron pulley, thirty-one and a half inches in diameter, on the fpindle of the pinion of a crane of the following defcription, *viz.*

Barrel, 30 inches diameter.
Wheel, 64 teeth.
Pinion, 8 ditto.
Top block, with three pullies of 12 inches diameter.
Bottom block, with 2 ditto. ditto.

To the large pulley I attached a fmall rope, for the purpofe of fufpending the weights in the hoifting of the different loads, and the refults were as follow:

The crane was loaded with,		Took to hoift the loads when reefed with the chain in grooved pullies. All the experiments were tried with the fame grooved pullies.	Ditto, when reefed with a half-worn tarred ftrand-laid rope $3\frac{1}{2}$ inches in circumference.	Ditto, when reefed with the chain promifcuoufly, as in the common way.
	lbs.	lbs.	lbs.	lbs.
Firft, - -	2000	63	74	80
Second, - -	1000	32	39	41
Third, - -	500	17	21	22
Total	3500	112	134	143

The flexibility is inverfely as thefe momenta, and proves the fuperiority of chains; for (on the average of the trials with the chain in the grooves;

One pound raifed - - - - - 31.25 lbs.
With a half-worn ftrand-laid tarred rope, three inches and a half in circumference - - - - - - 26.11 ditto.
And with the chain in the ufual way, only - - - - - - 24.47 ditto.

It alfo appears (contrary to the general opinion,) that chains are fafer than ropes; for it is an eftablifhed axiom, that thofe bodies whofe fibres are moft in the direction of the ftrain, are the leaft liable to be pulled afunder; and in our examination of the properties of a rope, we find that the ftrands crofs the direction of the ftrain in undulated lines, and confequently prevent its uniform action thereon. A rope is fubject to this inconvenience even when ftretched in a direct line, but more particularly fo when bent over a pulley, as in that pofition the upper fection moving through a greater fpace than the under one, is acted upon by the whole ftrain; and hence the frequent breaking of ropes in bending over pullies, from the double ftrain overloading the ftrands of which the upper fection is formed.

The links of a chain are fubject to the tranfverfe ftrain, where they move in contact; but as fuch ftrain is in proportion to the length of the bearings, it muft be very trifling. All the links having axles of their own, the chain moves fimultaneoufly with the ftrain, and both are in confequence retained in continual equilibrio. A chain in grooves will therefore fuftain as great a weight when bent

over a pulley, as it will in a direct line, and consequently is safer than a rope.

The Society for the encouragement of arts, manufactures, and commerce, having for many years past offered premiums for improvements in cranes, have therefore a large collection of models of different sorts. We have selected 3 of these, and have appropriated *Plate* XX. *Mechanics*, to the explanation of them. *Figs.* 1 and 2, are two elevations of a walking wheel crane laid before them by Mr. James White of Chevening, Kent, and for which he received a premium of 40 guineas in the year 1796. We have found it necessary to have new drawings made of this machine, as those published by the learned society are taken from the model left with them, and do not explain the manner in which the machine should be constructed.

Figs. 1 and 2, are two elevations of it at right angles to each other. A A is a large wheel, about 16 feet diameter, strongly framed and secured to its axis E, which is mounted upon pivots at its ends and inclined to the horizon in an angle of about 70 degrees, and consequently the plane of the wheel inclines 20 degrees. The rope of the crane is coiled round the axle and passes over a pulley *a*, (*fig.* 1.) to the gib of the crane, which is constructed in the usual method; F is a lever extending across the wheel and fixed at one end into an upright axis; G H is a short lever connected with an iron rod *e*, with a gripe *g*, which embraces part of the circumference of the wheel and prevents its turning, unless removed by pushing the lever F; *h* (*fig.* 1.) is a cord fastened to the gripe lever, and going over a pulley in the floor, having a weight suspended from it; this always gives the gripe a tendency to stop the wheel, and by the weight coming up to the pulley stops the gripe lever from going too far, when pressed by a man walking on the wheel. The wheel is turned by a man walking on the wheel and pushing the gripe lever F, so as to release the wheel which then turns (if the load be not too great) both by his weight and muscular exertion applied against the gripe lever.

The wheel is supposed to be erected in a warehouse, and an opening is made in the floor to allow the wheel to pass through. The man walks from the floor at *k*, up the wheel, which will always be at rest, unless he relieves it by pushing the lever F. The end, *l*, of the gripe is jointed to a stout upright beam going from the floor to the ceiling of the room where the crane is erected, and the rest of the gripe should be hung by small cords from the ceiling to prevent its falling down and getting from its work.

The properties of this crane are as follow: its simplicity consisting of a mere wheel and axle. Secondly, its only friction, exclusive of the pullies, is that on the two gudgeons of the shaft; and one of these supports the weight of the wheel, and of the man that works it, nearly in the direction of its point. Thirdly, it is durable, as is evident from the two properties above-mentioned. Fourthly, it is safe, for it cannot move but during the pleasure of the man, and while he is actually pressing on the gripe-lever. Fifthly, this crane admits of an almost infinite variety of different powers; and this variation is obtained without the least alteration of any part of the machine. If, in unloading a vessel, there should be found goods of every weight, from a few hundreds to a ton and upwards, the man that does the work will be able so to adapt his strength to each as to raise it in a space of time proportionate to its weight, he walking always with the same velocity as nature and his greatest ease may teach him. It is a great disadvantage in some cranes, that the smallest weight must be as long in rising as the largest, unless the man turn or walk with a greater velocity, which tires him in still greater proportion..

In other cranes, perhaps, two or three different powers may be procured; to obtain which, some pinion must be shifted, or fresh handle, applied or resorted to. In this crane, on the contrary, if the labourer find his load so heavy as to permit him to ascend the wheel without its turning, let him only move a step or two toward the circumference, and he will be fully equal to the task. Again, if the load be so light, as scarcely to resist the action of his feet, and thus oblige him to run through so much space, as to tire him beyond necessity, let him move laterally towards the centre, and he will soon feel the place where his strength will suffer the least fatigue, by raising the load in question.

It has been before observed, that, if left alone, this crane will naturally reduce itself to a state of rest, even though a weight were suspended to it. The means will appear to be the gripe, or brake at the top, and its lever, which stretches across the diameter of the wheel, at the height of a man's breast, when in an attitude of treading the wheel to the best advantage.

The next crane of the Society's which we shall describe, is one for which Mr. John Braithwaite received their gold medal. The description published in the *third volume* of their Transactions, is as follows:

The frame, which is wholly of cast iron, is formed of two circles, held together by three screwed bars, and standing on four feet; the crane wheel, which is inclosed within the frame, consists of three concentric toothed face-wheels, joined together by strong bars, whose axle is the barrel, on which the rope is coiled; in the front of the face-wheels runs a shifting arbor; on this arbor is a pinion, which may be brought to work in the teeth of either of the face-wheels, and thereby the power employed at the winch may be applied to raise a greater or lesser weight occasionally. A B C D E, *figs.* 3 and 4, is a frame of cast iron; F, G, H, three concentric face-wheels, united together by the eight straight bars, *a, a, a*; I K a sliding arbor, on which is fixed a pinion L; M the winch or handle; N a stop, which, when lifted up, permits the sliding arbor to be moved backward or forward; but, when down, retains it in its proper place; O a pall, or stop, which prevents the crane running back, but may be discharged at pleasure; P the barrel on which the rope is coiled.

We think a great improvement might be made in this machine, by putting on the arbor, I K, three pinions, one for each wheel; they should all be put loose upon the arbor, but either of them may be easily fixed to turn with it by a sliding coupling iron; which will only admit of one being engaged at a time. The wheels might then be beviled, which are found, by experience, to work better than the face-wheels: and the sliding of the arbor obliges it to be of greater length than necessary, and more liable to be strained or bent; we have seen such a contrivance in other machines which acted very well.

Fig. 5, is a contrivance of Mr. Joseph Dixon, for which the Society presented him with 15 guineas in 1793, which he calls a preservative-wheel; it is intended to be applied within-side of an ordinary vertical wheel, where the men walk in the inside, to prevent the danger to which they are continually exposed, by the load being too great for them; the wheel then runs back, and throws them about in the wheel, and frequently kills them. A E is the axis, or spindle of the walking-wheel; the arms are mortised into it at *aa*; E is the part where the crane rope winds; B, B, are two wheels fixed on the axis, and having at their peripheries six pullies,

over which ropes run, that are faftened at their extremities to two fegments of circles C, C; thefe are united together by a wooden bar D, which the men are to lay hold of and fufpend themfelves by in cafe of danger.

This machine would completely obviate the danger to which the men who work in thefe wheels are expofed, but it would, at the fame time, increafe the danger to thofe employed in other parts, as the men within the wheel would, by hanging themfelves to the bar D, remove all obftructions to the wheel's motion, and, without fome other contrivance of a brake-lever, the wheel would run down fo rapidly by the action of the load as to expofe thofe at the gib, and other parts, to great danger.

Mr. Ferguson contrived a crane (already defcribed) to remove the fame defect, where the walking-wheel had a ring of cogs round its outfide, working into a pinion, on whofe axis was a brake and racket-wheel, with a winch at the end for the man who managed the brake to affift occafionally in raifing the load. But the rapid motion of the circumference of thefe large wheels, in moft cafes, renders this contrivance inapplicable, unlefs a fmaller cog-wheel was fixed upon the fame axis with the walking-wheel.

Fig. 1, of *Plate* XXI. is a gib for a crane invented by Mr. Bramah, and defcribed by him in Nicholfon's Journal, 8vo. vol. viii. p. 99. The fupport for the gib is a hollow pipe or column, A, firmly fixed by a fquare flanch, bolted to beams in the ground, and the rope for the crane paffes through this pillar. The gib of the crane has two fockets, *a*, *a*, fitting to the pillar, fo that it can turn all round. A pulley, *b*, is fixed on the back of the gib and its edge hangs juft over the centre of the column: *d* is the pulley at the end of the gib. The crane rope, after going over the pullies *b*, *d*, paffes down the column, and goes round another pulley, to convey it to the crane-work, which may be of any of the kinds we have defcribed.

Fig. 2, is a very good kind of crane, as it requires no framing over it; it turns round upon a ftrong vertical beam, A B, moving between rollers fixed in the floor of the wharf at B, and going down below that 12 or 14 feet, where it works on a pivot. The beams of the gib are mortifed into the beam A B; the wheels are mounted in a frame formed by two caft iron croffes bolted to the beam, one on each fide; the barrel is one foot diameter; the great wheel has 100 teeth, and is four feet diameter; the fecond wheel has 31 teeth; and the laft pinion feven leaves. The winches can be applied to any of the wheels for different powers, when it is ufed on the barrel, or fecond wheel; the others are put out of geer by fliding their fpindles endways. The barrel and pullies fhould always be grooved, as in Mr. Smeaton's crane, where chains are ufed, though this is not fufficiently attended to by Mechanics.

Fig. 3, reprefents the tongs by which logs of timber are taken up with a crane, and the greater weight they bear the better they hold. *Figs.* 4 and 5, are two elevations of a crane by Mr. Valentine Gotilieb of Lambeth Marfh, London. The barrel, A, has a wheel fixed to it at each end; one, *a*, has 96 teeth, the other 90; *b* is an arbor with two pinions on it of eight teeth for the wheel 96, and another of 14 for the wheel 90; thefe pinions are at a fmaller diftance apart on their arbor than the two wheels, fo that they cannot be both engaged to the wheel at once, and by fliding it an end either wheel and pinion may be ufed for different work; *e*, *f*, are two ftops to hold it in either one; *h* is a fly on the fame arbor *b*, and *e* the handle. The original part of the crane is the gib; it is a large beam, H, placed horizontally, and running upon a roller at *k*, and its other end kept down by another at *l*; it has a pulley at its outer end, over which the rope paffes. The underfide of the beam is cut into teeth, forming a rack, and a pinion of eight leaves, on the fame arbor as the wheel *m*, moves the beam, fo as to bring the goods fufpended from its end into the houfe. H is the wall of the warehoufe, and the wheels are fuppofed to be placed in the roof. The wheel *m*, and the fly wheel, have endlefs ropes going round them to work the crane by, in the room below, if neceffary.

Crimson

CRIMSON, in *Dyeing*, is produced by various proceffes according to the nature of the fubftance employed, and the kind of ftuff deftined to receive the colour. Wool and filk are dyed either with cochineal or Brazil; with the former the colour is more fixed and permanent, and is called the true or fine crimfon; Brazil gives a fine colour, but does not refift the action of the fun and air fo well.

All the proceffes for dyeing wool crimfon with cochineal may be reduced to two. Either the fhade defired is given to cloth previoufly dyed fcarlet, or the cloth is dyed crimfon at once.

The natural colour of cochineal is crimfon, and it affords this colour both with alum and the folution of tin, when its effects are not modified by the action of tartar, as has been fhewn by Bancroft. When cloth therefore that has been dyed fcarlet in the ufual way is boiled in a folution of alum, the natural hue of the cochineal is reftored, and the cloth becomes crimfon. Alum, falts with earthy bafes in general, the fixed and volatile alkalies all effect this change; the quantity neceffary to produce any determinate fhade, varies confiderably with the nature of the water employed. Some which is loaded with earthy falts will anfwer the purpofe without the addition of alum, or any other fubftance whatever.

Hellot tried foap, foda, and potafh; all thefe fubftances produced the colour defired, but faddened it and gave it lefs luftre than when alum was employed. Ammonia, on the contrary, produced a very good effect; but it evaporates quickly from the bath and requires a confiderable quantity. Hellot replaced the ufe of it, by adding equal quantities of muriate of ammonia, or common fal ammoniac, and potafh; the ammonia was difengaged in the bath, and in this way the cloth inftantly took a very bright colour. He afferts that the colour is fo much heightened as to render lefs cochineal neceffary. Mr. Poerner has given nearly the fame procefs. He directs the cloth to be boiled an hour in a folution of common falt in the proportion of 2¼ ounces to 1 lb. of wool, and to let the cloth remain in it 24 hours after it is become cool. A bath is prepared with 1 ounce of cochineal, 2 drams (gros) of tartar, and 2 ounces of folution of tin for every pound of cloth, and in this it is boiled one hour. When wafhed it is fteeped in a vat, in which equal quantities of fal ammoniac and potafh, in the proportion of 6 drams of each to a pound of cloth, have been previoufly diffolved; it is fuffered to remain here 24 hours, frequently turning and moving it in the liquor. It is afterwards taken out and wafhed. The colour is a reddifh crimfon inclining to blue.

This mode of producing crimfon by the action of alkalies or alum, is generally reforted to when cloth dyed fcarlet has been ftained or fpotted by accident. Thefe defects are thus remedied or rendered lefs glaring. Muriate of foda, or common falt, has alfo the property of converting fcarlet to crimfon, and has long been ufed for this purpofe in Languedoc, according to the teftimony of Hellot.

To dye crimfon at once, a folution of two ounces and a half of alum, and an ounce and a half of tartar to every pound of cloth, is ufed for the boiling; the cloth is afterwards dyed with 1 ounce of cochineal. Solution of tin is commonly added, but in lefs proportion than for fcarlet. The proceffes employed vary greatly according as the fhade required is deeper or lighter, or more or lefs removed from fcarlet. Some ufe common falt for the boiling.

Mr. Poerner directs the boiling to be made with 3 ounces of common falt and 3 of alum, to 1 pound of cloth, and after fuffering it to remain 24 hours in the folution after cooling, to boil one hour in a bath compofed of 1 ounce of cochineal, 2 drams of tartar, and 2 ounces of folution of tin. The cloth takes a reddifh crimfon.

A bright reddifh crimfon of very agreeable hue may be obtained by boiling 1 lb. of cloth a full hour in a bath prepared with 3¾ ounces of alum and 2¼ ounces of tartar, fuffering it to remain 24 hours in the liquor after cooling. Then boil an hour and a half in a bath compofed of 1 ounce of cochineal only, without any other ingredient. If this cloth be fteeped 24 hours in a cold folution of 1½ ounce of fal ammoniac, and 1½ ounce of potafh in 20 lbs. of water, the colour becomes deeper, and another fhade of crimfon is by this means obtained.

Archil and potafh are frequently ufed for faddening crimfons and giving them more bloom, but the hue thus imparted foon vanifhes.

The boiling for crimfon is fometimes made after a fcarlet dyeing, by adding alum and tartar to the bath, and fome particular fhades of crimfon are faid to poffefs more bloom when dyed this way, than when frefh baths are ufed.

Crimfons in half grain are fometimes dyed by fubftituting madder for half the quantity of the cochineal, following in general the fame proceffes as for the grain crimfon. Other proportions of madder may be ufed inftead of half, according to the effect required.

The colour produced by Brazil is not fo permanent on wool as cochineal, it is neverthelefs employed. The cloth is boiled in a folution of alum, to which a fourth of its weight, or even lefs of tartar is added. A greater proportion of tartar inclines the colour too much to the fcarlet or yellow hue.

The cloth thus impregnated fhould remain feveral days in a cool place; after which it is dyed by boiling gently in Brazil liquor. The colouring matter which is firft depofited does not yield fo fine a colour, the coarfeft goods fhould therefore be paffed through the bath firft, and afterwards the finer ones. In this way a colour is obtained which ftands the action of the air tolerably well.

Mr. Poerner directs 1 lb. of cloth prepared with 5 ounces of alum, and 1 ounce of tartar, to be boiled one hour in a bath containing 6 ounces of Brazil, and 6 ounces of alum. The cloth acquires a deep brick red. When fteeped 24 hours in a cold folution of potafh, it becomes a fine reddifh crimfon. By preparing the cloth with alum and tartar, Mr. Poerner obferves that very good and ufeful colours may be obtained from Brazil, which are deeper and richer than thofe obtained on cloth prepared with alum, tartar, and folution of tin, or with tartar and folution of tin without alum. By varying the proportion of the ingredients, and ftill more by the action of potafh and fal ammoniac, thefe fhades of crimfon may be greatly modified. Colours obtain-

ed from Brazil may thus be rendered tolerably permanent, yet they are not comparable in this refpect with thofe obtained from cochineal or madder. A bloom is fometimes given to madder colours by paffing them through a decoction of Brazil, but this flight tinge foon fades and perifhes.

Mr. Guhliche gives a procefs, by which he pretends that fine and more permanent colours are obtained than by thofe in general ufe. He directs pure vinegar, or *aceto-citric* acid, or aqua regia, to be poured on Brazil rafped or chipped, till it is covered with the liquor; the mixture to be well fhaken, then left to fettle for 24 hours, after which it muft be decanted, filtered, and kept for ufe. On the refiduum, frefh water or vegetable acid is to be poured, and this to be repeated till all the colouring matter is extracted, when the wood will be found to be black. All thefe liquors are then to be mixed together for ufe.

The ftuff having been prepared with a flight galling of fumac, or white galls, is flightly alumed. After rinfing, it is entered wet into a bath prepared as follows: Some of the acid folution of Brazil is diluted with water proportionate to the quantity of ftuff, or the fhade of colour to be given. When this is fo hot that the hand will juft bear it, folution of tin is poured in till it is of a fire colour: it is then ftirred and the ftuff entered. In half an hour it is taken out and wafhed. The remainder of the bath may be ufed for lighter fhades, but thofe ftuffs only muft be galled that are for deep ones. The aceto-citric acid, as it is called by Berthollet, is a liquor of which Mr. Guhliche makes great ufe in dyeing under the name of vegetable acid fpirit, which he prepares in the following manner: He takes any quantity of lemons; thofe of which the rind is rotten will do, removes the peel and the fkin that adheres to it, and flices them into a veffel, which fhould not be made of wood. He fprinkles them with a quantity of good vinegar, and then fqueezes out the liquor through a flannel by means of a prefs, and filters the expreffed liquor through paper. It may be ufed with fuccefs in this ftate, but it is apt to grow mouldy and the acid is watery. In order therefore that it may keep, and not dilute the baths into which is put, he directs it to be purified and concentrated as follows: The liquor is to be expofed to the fun till a fediment forms and it becomes clear, it is then to be filtered and diftilled on the fand bath. The receiver is to be changed when the liquor that drops becomes acid, and the diftillation continued till oily ftreaks are perceptible in the neck of the retort.

The acid found in the receiver is to be kept for ufe.

On the foregoing procefs for obtaining aceto-citric acid, we fhall obferve that if the acid be ufed in its recent ftate, as expreffed from the lemons, it is indeed a mixture of citric and acetous acid, but the rectified and concentrated fpirit of Mr. Guhliche is, after all, nothing but diftilled vinegar. Citric acid will not rife in diftillation; it may be decompofed by heat, but cannot be driven on like acetous acid; this procefs of rectification is therefore a feparation of the acid of the lemons from the vinegar they were fprinkled with, and proves the inutility of one of the ingredients at leaft of this compofition. Of the efficacy of galls in rendering the colouring matter of Brazil more permanent there can be little doubt, but it has a tendency to debafe the colour, and it is with reafon, that Mr. Guhliche obferves that the galling fhould be employed only for the deeper fhades.

Silk acquires from cochineal a colour which is diftinguifhed from the falfe crimfon obtained by means of Brazil.

Silk intended for cochineal crimfon ought not to be boiled with more than 20lb. of foap to 100 of filk, as the yellow caft which filk has when imperfectly fcoured is favourable to this colour. It is fometimes imparted to it by a flight tinge of annotto, when white filk is to be dyed crimfon.

When the filk is well cleaned from the foap by wafhing, it is foaked in a ftrong folution of alum, in which it is generally left all night, and next day is wrung, wafhed, and twice beetled at the river.

The bath is prepared as follows: Into the dyeing veffel, half, or two thirds filled with boiling water, from one to two ounces of pounded white galls are thrown in for every pound of filk. After boiling a few minutes, two ounces of cochineal or more, according to the ftrength and fulnefs of the fhade required, are added for every pound of filk, and for every pound of cochineal, one ounce of tartar. When this is diffolved, an equal weight of the folution of tin is added; the ingredients are all well ftirred, and the bath filled up with cold water. The proportion is generally about eight or ten quarts to every pound of filk. In this the filk is entered and worked till it appears quite uniform in colour; the fire is then increafed, and the bath made to boil two hours, turning the filk from time to time. The fire is then withdrawn, and the filk left in the bath a few hours longer. It is then wafhed at the river, twice beetled, wrung, and dried. The folution of tin for this procefs ought to contain more tin than is ufed in the compofition for fcarlet, otherwife the colour is too bright, and not fufficiently full and deep. Macquer directs the folution to be made with one pound of nitric acid, two ounces of fal ammoniac, two ounces of tin, and twelve of water.

If the colour is to be faddened, the filk after wafhing is paffed through a folution of fulphate of iron, more or lefs ftrong, according to the fhade required: if the crimfon fhould have a tinge of yellow, a greater or lefs proportion of the decoction of fuftic muft be added to the folution.

White galls are preferred, becaufe the black or blue galls debafe the colour of the cochineal; and even white, when ufed in too great a quantity, dull the crimfon very much. Macquer pretends that the galls ferve only to increafe the weight of the filk; their general effect, however, is that of giving greater permanency to the colours, and in crimfons of the deeper fhades their ufe is indifpenfable.

The quantity of folution of tin employed in the foregoing procefs is very fmall. If ufed in the bath in the fame proportion as for dyeing wool fcarlet, the filk would lofe its luftre, and acquire but a faint colour. Macquer and Scheffer have however each publifhed proceffes for dyeing filk rofe or poppy colour, which differ only in a few particulars from the ordinary mode of dyeing fcarlet, the folution of tin being employed cold to avoid its ftrong action on the filk.

In the procefs which Macquer publifhed in 1768, the folution is prepared by adding three ounces of tin by little at a time, to a mixture of four ounces of nitric, and two of muriatic acids. When the folution is finifhed, 6 lbs. of filk that have already had a flight ground of annotto, are immerfed, and remain in it half an hour. It is then wrung and wafhed till it no longer renders the water turbid. It is dyed with four ounces of cochineal, and one ounce of tartar, for every pound of filk. Thefe are boiled up in water, and afterwards cooled down till the hand can bear the heat. The filk is then entered, and the fire increafed; after boiling one minute it is withdrawn and wafhed. By this procefs the filk has acquired an increafe of one fourth of its weight. Its colour refifts foap, and is much more permanent than that which Carthamus affords.

In 1751, Scheffer publifhed a defcription of the following procefs. He diffolved one ounce of tin in a mixture of

four ounces of nitric acid, and one of common falt. The folution was diluted with twice its quantity of water, and the filk fteeped in it 24 hours. When withdrawn it was wafhed till the water no longer appeared milky, and dyed with four fifths of its weight of cochineal in a fmall quantity of water. The bath retains a confiderable portion of colouring matter which may ferve for dyeing filk a lighter fhade, or even for dyeing crimfon by the ordinary procefs. It may be ufed alfo for dyeing wool.

Scheffer defcribes the following varieties of his procefs for obtaining different fhades. If the filk be wrung out of the folution of tin, left all night in a cold folution of one ounce of alum in a quart of water, wrung, dried, wafhed, and afterwards dyed with cochineal, it will take only a pale poppy colour. If the filk be fteeped twelve hours in the folution of tin diluted with eight parts of water, and then left all night in the folution of alum, wafhed, dried, and paffed through two baths of cochineal as before, adding to the fecond bath a little fulphuric acid, the colour will be a fine poppy red.

In the experiments made by Berthollet on this fubject, the folution of tin, which anfwered beft for dyeing filk, is that which he has directed for the fcarlet dye, and is made by diffolving flowly in one pound of nitric acid, two ounces of tin, and two ounces of fal ammoniac: the falt to be diffolved firft, and the tin added afterwards in fmall portions at a time, ftirring it frequently to incorporate the folution fully. When finifhed and decanted from the black fediment which is depofited, it is diluted with one fourth of its weight of water. The nitric acid employed fhould be of the ftrength of 30° of the hydrometer of Beaumé, which correfponds with a fpecific gravity of about 1.26.

Solutions containing a greater proportion of tin gave deeper fhades. The colour obtained by the above, was a fine cherry colour fufficiently bright.

Brazil wood is ufed for dyeing filk what is called *falfe* crimfon, to diftinguifh it from that produced by means of cochineal, or *grain* crimfon, which is much more permanent. Vinegar is ufed to diftinguifh the true colour from the falfe, but this proof is fallacious, fince the Brazil crimfon dyed with the folution of tin, refifts the action of vinegar like cochineal, though that dyed with alum does not.

Silk intended for this crimfon, fhould be boiled with foap in the proportion of twenty pounds to a hundred of filk, and afterwards alumed. Lefs alum is required for this than for grain crimfon. After rinfing in the river, it is paffed through a bath more or lefs charged with the decoction of Brazil according to the fhade required. If water, free from earthy falts, be ufed, the colour is too red for crimfon; the proper hue is given to it by paffing the filk through a flight alkaline folution, or by adding a little alkali to the bath. Working the filk in hard water till it has acquired the proper fhade, will anfwer the fame purpofe.

Logwood liquor may be added to the Brazil, to deepen the fhade of crimfon, and a little alkali ufed with it alfo when the fhade defired requires it.

There is the fame objection to the ufe of the folution of tin in dyeing filk crimfon with Brazil as with cochineal; filk has not that powerful attraction for the colouring matter combined with tin that wool has; the greater part therefore feparates and contracts no union with the ftuff. Bergman, however, remarks that the colours imparted to filk by different dye woods, may be much improved by fteeping the filk in a cold folution of tin. A ftrong decoction of Brazil, fays he, gives to yellow filk prepared in this way a fcarlet colour inferior indeed to that of cochineal, but finer and more permanent than if it be fteeped in alum only, and as capable of ftanding the proof by vinegar as crimfon or poppy in grain. Mr. Guhliche defcribes a procefs, in which he ufes folution of tin in the bath to give filk a fire colour. He directs the filk to be galled with a folution of galls in white wine, afferting that an aftringent folution thus made preferves the brightnefs required in filks much better than one prepared with water. With this folution he mixes water till it has acquired a yellow colour, and impregnates the filk well with it, leaving it to fteep cold for feveral hours. He then preffes out the liquor ftrongly, but without rinfing the filk which he dries, and afterwards foaks for twelve hours in a folution of alum, containing four ounces for every pound of filk. The filk taken out of the alum water is wrung, and entered wet into a bath of Brazil, after adding to it an ounce of folution of tin. The remainder of the bath may be exhaufted for lighter fhades. If the colour be required more approaching to orange, the filk is not to be galled, but to be alumed cold with two ounces of alum to the pound of filk, after which it muft be dyed orange with annotto, without boiling, and before it dries dyed in the Brazil bath. The author confeffes that thefe colours, particularly the latter, are not very permanent. For rofe colours he omits the galling, and for the aluming ufes only two ounces of alum to the pound of filk. For light fhades he recommends the folution of alum to be decanted from the fediment that may have been depofited, and prefers dyeing them cold, ufing a bath richer in colour. The filk is to be taken out as foon as it has acquired the proper tint, and the bath may be exhaufted for other fhades. With thefe precautions he affures us, that fine colours of tolerable permanency may be obtained.

The crimfon imparted to cotton or linen by cochineal and Brazil, has little folidity, and is on that account but little ufed, more efpecially as madder imparts to thefe fubftances, properly prepared, one of the moft beautiful and permanent colours which the art of dyeing can produce.

As this however is not the place in which to enter into a detail of the operations of the Turkey or Adrianople red, which we purpofe to treat at large under another head, we fhall give fome account of the proceffes that have been propofed and practifed with more or lefs fuccefs for producing a fine crimfon colour upon cotton by means of cochineal and Brazil.

Mr. Poerner has made many experiments with different mordants, as alum, folution of tin, fal ammoniac, potafh &c. for dyeing cotton with Brazil, ufed either in the bath or in the preparation of the cotton. He could not produce a colour, however, that would ftand wafhing with foap, though fome would ftand the action of the air and wafhing with fimple water very well. He recommends cotton thus dyed, to be dried in the fhade.

Mr. Berthollet received from Mr. Brown the following procefs for dyeing cotton a crimfon colour, which is ufed by fome manufacturers.

A folution of tin is prepared in the proportion of nitric acid two pounds, muriatic acid one pound, tin eight ounces and water one pound. The liquids being well mixed, the tin is added by little and little. For a piece of cotton velvet weighing fifteen or fixteen pounds, a bath is prepared confifting of boiling water four parts, ftrong decoctions of galls two parts. Having raked up the bath, the piece is entered and worked for half an hour, and left to foak two hours, when it is taken out and left to drain. Another bath prepared with three buckets of boiling water, and one of decoction of Brazil wood, alfo boiling, is to be raked up and the piece worked in it an hour. This bath is to be thrown away, the veffel wafhed out and then filled with a pure de-

coction of the wood, in which the piece is to be worked half an hour, and then raised on the winch. A bath of very clear river water, with a quart of solution of tin, being prepared and raked, the piece is to be worked in it a quarter of an hour. It is then wound on the winch, and set on the vessel containing the decoction of Brazil, one sixteenth of which is to be taken out and replaced by an equal quantity of boiling decoction. This being raked, the piece is worked in it half an hour, wound on the winch and carried back to the vessel containing the solution of tin. These operations are performed alternately six or eight times, observing each time to take out a sixteenth of the bath of Brazil wood, and replace it with an equal quantity of boiling decoction of the same wood, to rake the bath of composition each time, and to finish the dyeing with the latter. The piece is to be washed in the river, and dried in a dark place.

With the aluminous mordant cotton takes a full and tolerably bright crimson from Brazil, the permanency of which is considerably increased by previously subjecting the cloth to the operation of galling. The printer's mordant prepared with acetite of lead and alum, is best for this purpose. When used diluted, the shades of crimson and rose colour are very delicate, but so fugacious as not to support the action of the sun and air unimpaired a single day. Sumac used in the bath along with Brazil contributes greatly to its fixity; the stronger shades dyed this way support the action of the air tolerably well, and have greatly the appearance of a madder red.

Cochineal is little used for dyeing cotton and linen, since the colour is much less permanent than that obtained from madder. Scheffer however has described a process which may be employed. The cotton is to be steeped 24 hours in a cold solution of tin, it is then wrung, washed, and boiled a quarter of an hour with four-sixths of its weight of cochineal. It takes a light red, and resists the sun and air for a time, but not soap. Little use appears to have been made of this process of Scheffer, though it is probable that Dr. Berkenhout availed himself of it some years afterwards, when he pretended to have discovered the means of dyeing scarlet crimson, and other colours upon cotton and linen; and though his process was not materially different from Scheffer's, nor in any respect preferable, he obtained 5000 *l.* from the British government, as a reward for making it public.

As it excited considerable interest and some contention at the time, we shall present our readers with the following detail of the process, as it was communicated by order of the lords of the treasury to the company of dyers in the city of London, Aug. 16th. 1779. *viz.*

" Cotton or linen, either in yarn or piece, should be perfectly wet with hot water, and then wrung out, as is the common practice.

" This being done, it must be perfectly soaked in a solution of tin diluted with an equal quantity of clear soft water.

" The cotton or linen being so far prepared, must be wrung out, but not forcibly; it is then to be nearly dried, laying horizontally upon a hurdle with a double linen sheet between them, and covered with the same.

" The solution of tin being for scarlet, must be made of nitrous acid, and not of aquafortis; but for crimson, aquafortis must be used, and the bloom is to be given after it comes out of the dye, by a small quantity of sal ammoniac and pearl ashes dissolved perfectly in warm water, but this water must not be more than milk warm.

" The colouring vat for the scarlet or crimson is simply cochineal in water no hotter than the hand will bear, and as vegetable matter receives only the small particles of the colour from the nature of its pores, two ounces to a pound of the materials dyed may be necessary: but cotton or linen fresh prepared, will draw from the same vat, heated as before, all the inferior shades from scarlet and crimson, and if any colour still remains in the vat, it may be taken out entirely, by wool prepared in the usual manner.

" The same preparation of tin serves for the green and yellows, with the same materials only that are employed by dyers, except the best yellow, which is produced from turmeric.

" It is necessary to observe, that after the preparation has been made use of for scarlet or crimson, the residue continues sufficiently strong for greens or yellows, even after it has been kept a considerable time.

" N. B. To make the best solution of tin with nitrous acid, it is necessary to have the strong smoaking spirit, to which an equal quantity of the purest river water must be added, and the proportions of the following ingredients are to the weight of spirits $\frac{1}{16}$ sal ammoniac, $\frac{1}{32}$ refined nitre, dissolved by little at a time. In this aqua regia, dissolve $\frac{1}{8}$ of granulated tin also by small quantities, to prevent too great an ebullition which would weaken the solution considerably. The ingredients and proportions are the same when a solution is to be made with aquafortis, but that spirit in general will not bear any water when a perfect solution is intended."

Besides the fugitive nature of the colour dyed by the above process, it was found that the texture of the cloth was considerably injured, and it was soon laid aside, or rather was never adopted. If, notwithstanding the want of sufficient permanency, however, the colour which cochineal affords, should still be required; the best way of producing it, according to Dr. Bancroft, is to soak the cotton (previously moistened) about half an hour in a diluted solution of murio-sulphate of tin; then wring or press out the superfluous part of the solution, and plunge the cotton into water, in which as much, or nearly as much clean potash has been dissolved as will neutralize the acid still adhering to the cotton, so as to precipitate the oxyd of tin, and cause it to be more copiously deposed or fixed in the cloth, which being afterwards rinsed in clean water may be dyed, with cochineal in the usual way. A full bright colour may be given to cotton in this way, which will bear a few slight washings with soap, and a considerable degree of exposure to air. The murio-sulphate of tin, on which Dr. Bancroft lays great stress, as well for the above process as for dyeing silk crimson, is prepared by dissolving 14 ounces of tin in a mixture of two pounds of oil of vitriol with three of muriatic acid. The muriatic acid should be first poured upon the granulated tin in a large glass vessel, and the oil of vitriol afterwards added slowly; and these acids mixed should be left to saturate themselves with tin, which they will do in time without artificial heat; but the solution will be rapidly promoted by a sand heat.

Under the head of cochineal we have given a short account of its use in calico-printing in dyeing crimson, to which we must refer our readers as well as to the article Colour for other details connected with the subject. The colours produced from madder with the aluminous mordant in the ordinary processes of this art, strictly speaking, belong not to the class of crimson, yet by repeated branning, boiling in soap or alkalies, the yellow or faun coloured principle which this root contains, may be nearly extracted, and tolerable crimsons obtained. The addition of a small quantity of solution of copper to the acetite of alumine, gives the

colour a crimſon hue of no great luſtre, but very permanent.

The following proceſs by Mr. Grouſe, affords a colour of leſs intenſity indeed, and ſolidity, but ſcarcely inferior in beauty, to the Adrianople red.

Prepare a mordant by diſſolving 4 lbs. of acetite of lead, and 4 lbs. of alum in a gallon of pure water, and after decanting the ſupernatant clear ſolution from the precipitate which forms, thicken it with gum to the conſiſtency required. If the work requires the mordant to be *ſightened*, add a little infuſion of cochineal till it is ſufficiently tinged to enable the printer to obſerve the progreſs of his work. Keep the goods from four to ſix days after printing, in a warm place, to facilitate the liberation of the acid; rinſe them five minutes in a copper of water at 120°, with two good ſpade-fulls of cow dung, after which waſh and rinſe them in clean water ſeveral hours, alternately winching, waſhing, and ſuffering them to ſteep in the river. Laſtly, winch five minutes in a clean hot water copper at 120°, and after rinſing and waſhing again in the river, dye them as follows. Into a dye copper of 300 gallons capacity three parts filled with clean water, free from all accidental impurities, and not diſcoloured either by rain or floods, put 20 lbs. of the beſt crop madder, and 60 lbs. of good ſweet bran. Mix well, and bring them up quickly to a boil, and keep them in a ſtate of ebullition 20 minutes. Add cold water ſufficient to take the copper off the boil, then enter two pieces, winching them briſkly and keeping them down with the copper ſtick the whole time they are in. Bring the copper up to a boil again, and in 8 or 10 minutes, according as the ſhade required, the goods will have acquired their full colour. Enter two more pieces after theſe are withdrawn, and keep them in a few minutes longer; they will be ſcarcely inferior to the former, but as the copper becomes exhauſted, every ſucceeding ſet will acquire leſs colouring matter than the preceding, and if the operation be continued upon ſeveral ſets without refreſhing the copper, the laſt will acquire only a pale but delicate roſe colour. If the whole are required to be full deep colours, the copper muſt be ſupplied with a regular charge of bran and madder after every ſecond ſet, but to exhauſt the bath fully, and proceed with due regard to economy, the ſtrong colours ſhould be dyed firſt, and the pale and more delicate ſhades afterwards.

Waſh them well after dyeing, and bran them at a boil. The colour improves much by this laſt operation, which may be repeated on the ſtronger ſhades till the colour has acquired its proper hue, and the whites are good. See MADDER.

Crucible

CRUCIBLE, in *Chemistry*. Crucibles are fmall veffels made of earthenware metal, or other materials, employed by chemifts in operations with the naked fire, fuch as fufions and reductions of metallic ores in the fmall way, vitrifications of earthy mixtures, calcinations, &c. &c. The conftruction of thefe veffels is of no fmall importance to the chemift; and many obfervations will fuggeft themfelves with regard to their felection and proper ufe.

1. *Of earthen crucibles.* Formerly, when chemifts made their own crucibles and fire-pots, the fubject engaged much of the attention of fuch eminent practical operators, as Pott, Glauber, Agricola, Cramer, &c. and more lately a confiderable improvement has been made by that eminent fcientific manufacturer, the late Mr. Wedgewood.

A pottery ware, which fhould unite all the requifites for a good crucible, fhould be infufible at almoft any heat, clofe and compact in texture, fo as to retain faline and metallic fluxes for a confiderable time, without being materially acted on by them, or allowing them to pafs through; and fhould be able to bear fudden changes of temperature, without cracking or fplitting. It is found, however, that all thefe requifites are incompatible in the fame ware; fo that a felection muft be made, according to the intended ufe.

For enduring the moft intenfe heat, without fufion, the hard, coarfe, brown crucibles, originally made at Waldenburg, in Heffe, have long been the moft efteemed. They are manufactured, according to Pott, by mixing a very refractory clay with a coarfe fand, the finer parts of which have been feparated by the fieve and rejected. Thefe veffels are not turned on the potter's lathe, as this would require a confiderable portion of water to bring them to the requifite degree of plafticity, but the mafs is barely moiftened, and is then fafhioned into the proper fhape, by being ftrongly rammed into an iron mould. The crucibles are then very flowly dried and baked. The genuine Heffian crucibles are extremely hard, and (unlefs filled with any fubftance that acts as a powerful flux) they are only foftened, but not melted down, by a heat of fufficient intenfity for any chemical operation. Though the coarfenefs of their texture tends to render them porous, this defect is counteracted, in a great meafure, by the very fmall quantity of water ufed in making them, and the confequent fmallnefs of the

shrinkage whilst drying; and their coarseness enables them to bear a pretty rapid heating and cooling without cracking.

The ordinary brown crucible ware used in this country, is whiter and finer than the Hessian, but is softer, more crumbly, and much more porous; so that litharge, when in fusion at a full red heat, runs through this ware nearly as easily as water soaks through a sponge. It is also more fusible than the Hessian, though it is sufficiently refractory for most purposes.

The most infusible material for fire-pots that is known, and which resists the operation of saline fluxes for the longest time, is a mixture of burnt and unburnt clay; and this is the composition of the large pots or crucibles used in glass-making. The peculiar advantage of this mixture is, in substituting baked clay to sand, or any other siliceous earth, and thus increasing the proportion of alumine, which is an earth of difficult solution in fluxes, and diminishing that of silex, which is more soluble.

Crucibles intended for the fusion of metals are much improved by a mixture of plumbago. This substance is infusible *per se*, and being protected from the action of the air by being involved in the clay, its carbonaceous ingredient escapes combustion. It has the additional advantage of having no affinity whatever with the earths, and, therefore, does not dispose them to fusion; and the unctuous softness of this material gives a great smoothness to the surface of the crucible, which prevents it from detaining any portion of the melted material when poured out. The black-lead ware will bear sudden heating and cooling better than any other; and it is so soft, that it may readily be sawed or cut with a jagged knife, whereby the chemist may easily fit himself with stoppers, covers, &c.; but its extreme porousness renders it unfit to retain any kind of saline flux.

The useful fire-ware invented by Mr. Wedgewood is a very fine, hard, close-grained porcelain biscuit, made of very pure clay and silex, which are brought to extremely fine powder before they are worked. This gives a closeness of texture superior to any other pottery; so that crucibles made of it will long retain saline fluxes; and retorts will serve for the distillation of the most corrosive liquors, without requiring any glazing. Experience has shewn, however, that no kind of earthenware remains impervious to air, when very strongly heated. The great inconvenience attending the Wedgewood fire-pot ware is, its extreme liability to crack whilst heating or cooling, which is owing to its porcellanous hardness, and the closeness of its texture. This inconvenience is, in some measure, remedied, by giving the crucible a slight coating of loam or clay.

It is often required, in chemical operations, to line the inside of a crucible with charcoal; as, for example, in the reduction of many of the simple metallic oxyds, or carbonated oxyds, such as the oxyds of manganese, copper, or lead, and for other purposes. This is sometimes done by cutting down a piece of charcoal to fit the cavity of the crucible, and then scooping a hollow in the charcoal; but it is a better and more speedy way to mix up some charcoal powder with a very little linseed meal, to moisten the mass just sufficient to make a slightly adhesive mass to line the crucible with it, and to dry it in a red heat, by which the volatile parts of the linseed fly off, and a sufficiently firm charcoal is left.

The form of the ordinary earthen crucibles is round, or three-cornered, or sometimes barrel-shaped; and they are usually furnished with stoppers of the same material, with a small hole through the top, opening obliquely, to allow the escape of any vapour, when the joining is closed by lute, and at the same time to prevent any of the dust of the fuel from falling in. As the lower part of the crucible would escape the greatest heat of the furnace, if put immediately upon the bars, and would be liable to crack by the current of cold air, the crucible is generally set on a solid earthen stand, which raises it an inch or two from the grate. The lid of the crucible may be luted on by a mixture of clay and sand; or, if it is required to be quite impervious, a mixture of pipe-clay, with about a tenth of glass of borax, may be employed, which, in a red heat, consolidates into a semi-fused tenacious mass.

Crucibles are also made of silver, iron, and platina. A silver crucible is almost indispensible in the analysis of earths and stones when they require to be first treated with caustic alkali; for, if earthen vessels are used for this purpose, the alkali acts also on the substance of the crucible, and thus much confusion is introduced in the process; whereas pure silver is not in any way acted on by alkali. The silver employed for this purpose should be freed from alloy, either by cupellation, or by being recovered from luna cornea. Silver, when perfectly pure, and laminated into a thin plate, is fusible at a full red heat, not more intense than can be made in a common fire; so that a crucible of this material will but just bear the heat required for the perfect fusion of the fixed alkalies, and will hardly retain the melted alkali for any great length of time. It is found, however, that this heat is by no means necessary, for most earths are completely *resolved*, or rendered soluble in water or acid, by previous ignition with alkali, for about an hour, in a heat short of fusion.

When a very strong heat is required to be given to the mixture of alkali and earths, chemists sometimes employ an iron crucible, previously cleaned and smoothed on the inside, which is often found very useful for other purposes.

Lastly, we may mention platina as a material for crucibles, which has been found of such singular utility for a vast variety of uses, that it is almost indispensible to the analytical chemist. Platina has the advantage of bearing the utmost intensity of heat without fusion, and not being in any degree oxydated by exposure to air, the smoothness and polish of the surface remain uninjured; so that substances which are heated in it may be detached with great ease and accuracy. There are few substances that act on platina; so that most operations that require heat may be performed safely in vessels made of this valuable metal: the particular mode of working it will be mentioned under the article Platina. It unfortunately happens, however, that the alkalies, when in strong fusion, dissolve a sensible portion of this metal; and hence it is not equally valuable with pure silver under these circumstances. When platina crucibles are strongly heated, in contact with coak or coal, they should be inclosed loosely in crucibles of earthenware, otherwise the vitreous slag of the coal is apt to adhere strongly to the outside of the platina vessel, and cannot be got off without much difficulty.

Cumberland

CUMBERLAND, in *Geography*, a maritime county in the northern part of England, bordering Scotland, is bounded on the weft by the Irifh Sea, into which its weftern coaft projects, fomewhat in the form of a bow, to an extent of nearly 70 miles; on the north it is feparated from Scotland by Solway Frith, the Scots Dyke, and the river Liddal; its eaftern fide is fkirted by the counties of Northumberland and Durham, the dividing limits being moftly artificial; to the fouth its boundaries are Weftmoreland and Lancafhire: from the former it is partly feparated by Ulls-water and the river Eamont, and from the latter by the river Duddon. The greateft extent of the county is about 80 miles, but its mean length not more than 60; its general breadth is nearly 35; and its circumference 224. It contains 970,000 acres: of thefe 342,000 comprife the mountainous diftricts; 470,000 are enclofed, and chiefly under cultivation; 150,000 are in low commons, capable of improvement; and 8000 in lakes and waters. Cumberland is divided into five wards, fynonymous with the hundreds in other counties; but fo called here, from the inhabitants of each divifion being formerly obliged to keep watch or ward againft the irruptions of the Scots, in times of warfare. It contains one city, Carlifle, 17 market-towns, 112 parifhes, 22,445 houfes, and 117,230 inhabitants. The ward of Allerdale, above Darwent, is in the diocefs of Chefter; all the other part of the county in that of Carlifle. The reprefentatives in parliament are fix, *viz.* two for the county, two for Carlifle, and two for Cockermouth. Cumberland pays one part of the land-tax, and provides 200 men for the militia.

The furface of the county is extremely irregular and broken. The fouth-weftern diftrict exhibits a gigantic combination of lofty, rugged, and rocky mountains, promifcuoufly thrown together, but enclofing many beautiful, though narrow, vallies, as well as fine lakes, rivers, and fome extenfive woodlands. On the eaftern confines, another range of hills ftretches along to Scotland, but poffeffes much lefs picturefque beauty than the former. In the front of this laft affemblage, a confiderably broad tract of low ground extends the whole length, unobftructed by any high mounts, partly cultivated, partly heathy common, and watered by the Eden, and numerous brooks and rivulets. This tract becomes very extenfive before it reaches Carlifle; ftretching acrofs the county to Wigton, and thence towards Workington, including all the northern part of the county. Along the weftern fhore there is a ftrip of cultivated land, from two to four or five miles in width. The woodlands are but few; and the general appearance of the county is bleak and naked, from the extenfive moors which fo frequently prefent themfelves to the eye of the traveller. The foils of this diftrict are exceedingly various, but have been claffed under the divifions of fertile clays, or ftrong rich loams, which occupy

but a ſmall portion of the county, and are chiefly appropriated to the growth of wheat; dry loams, including the different degrees from the rich brown loams to the light ſandy foils, and occupying the greater portion of the land; wet loam, generally on a clay bottom, and adapted to grazing; and black peat-earth, which is very prevalent in the mountainous diſtricts, and particularly thoſe adjoining Northumberland and Durham. The encloſed grounds are kept free from moles by an excellent practice obſerved in the different pariſhes, of hiring perſons to deſtroy them for a term of years, at a certain annual ſalary, which is raiſed like the regular parochial taxes, and does not exceed an halfpenny *per* acre.

The buildings of this county are chiefly of ſtone, except in the market-towns, where the houſes are generally of brick; and near the borders of Scotland, where they are moſtly conſtructed with clay or mud. Moſt of the old farm-houſes, cottages, and out-houſes, are thatched with ſtraw, and the ſtones of the walls laid with clay inſtead of mortar; but the more modern buildings are generally covered with ſlate, and their walls cemented with lime: in thoſe diſtricts, however, where clay or mud walls prevail, the advances of modern improvements are admitted with ſome reluctance; the people conſidering them as an expenſive and unneceſſary luxury. Many of the houſes are covered with a very fine blue ſlate, the beſt kinds of which are procured in Borrowdale.

The principal manufactures of Cumberland are the ſpinning and weaving of cotton into calicoes, corderoys, and other articles; and the printing of cotton. The former has not been many years introduced: it was firſt planted at Dalſton, and ſoon extended to Carliſle, Warwick-Bridge, Corby, Comerſdale, and a few more places. The ſeat of cotton-printing is at Carliſle, the population of which place has thereby been much increaſed. In ſome of the market-towns are ſmall manufactories of checks and coarſe linens. At Egremont eighteen looms are employed in the manufacture of ſail-cloth; and at Whitehaven, where it was only introduced in 1786, ſeveral hundred hands are employed in the different branches of the ſame manufacture. Three or four paper-mills are employed in different parts of the county; a manufactory of coarſe earthen ware has been long carried on near Dearham; and near Workington are the Seaton iron-works, which employ ſeveral hundred workmen. Many private families knit and ſpin their own ſtockings; and every village is ſupplied with a weaver or two, who weave their home-made cloth.

The mineralogical ſubſtances of Cumberland are extremely rich and variegated, and exiſt in ſuch abundance in the different parts of the county, that a deſcription of the whole would, of itſelf, conſtitute a work of conſiderable magnitude. In the calcareous genus is limeſtone, of various colours, texture, and hardneſs. The quarries at Overend contain impreſſions of many kinds of ſhells, with ammoniæ, entrochi, and aſteriæ; and a great variety of marine exuviæ are found in the limeſtone on the moors near Giſland Spa. Marble, with ſhells in it, of a browniſh colour, is met with at Little Stainton and Dacre; duſky-green, veined with white, at Croſs-fell; yellowiſh, grey, lead-colour, and brown, with or without ſhells, on the banks of the Peteril; and blueiſh-black, clouded with lead-grey, veined and ſpotted with white, hard, free from cracks, and admitting of a fine poliſh, near Kirkoſwald. Beautiful ſpecimens of ſpar of various colours, amorphous, and cryſtallized in different forms, are found in the lead mines of Aldſton-Moor; and, ſince the ſtudy of mineralogy has become faſhionable, have been ſold for conſiderable ſums. In the mines between Keſwick and Aldſton it has been met with, cryſtallized in hexagonal priſms, terminated at one end by a pyramid. Gypſum is found in many parts of the county: its colour is moſtly white, veined, clouded, and ſpotted with red; ſometimes brown and grey; of compact, even fracture. It frequently, however, exhibits a conſiderable variety of appearance, even in the ſame quarry; and at Newbiggen is met with not only compact, but ſplintery, fibrous, foliated, and cryſtallized: in the latter ſtate, the cryſtals are pure and colourleſs, arrow-headed, and irregularly diſpoſed, forming the reſemblance of a cock's-comb. It lies embedded in red argillaceous marl, between two large ſtrata of ſandſtone: the upper, ſolid, hard, and fine-grained; the under, looſe, friable, and coarſe. The ſtratum varies conſiderably in thickneſs; and in ſome places, immediately below it, there is a thin bed of a ſoft umber-like ſubſtance, which, on examination, appears to be decayed wood. The lead-mines of Aldſton-Moor contain a great variety of fluors, compact, foliated, amorphous, and cryſtallized. The colours are red, green, blue, yellow, purple, violet; and of all gradations, from very pale to almoſt black. They are ſometimes found ſtudded with brilliant quartz cryſtals, and with cryſtallized galena. In the magneſian genus is mica, which is found of many different colours, interſperſed and incorporated with ſeveral kinds of ſtones, and particularly in moſt of the ſandſtone rocks. Spangles of ſilvery mica are met with in a red, ſlaty, friable ſtone, near the river Caldew, in the quarries on the Peteril, and various other places. The ſteatites, ſemi-indurated, white, ſtreaked with pale green, has been found at Hill-Top and St. John's; and ſome of the ſolid white kind in Langnor iron-mine, at Borrowdale, and at one or two other places. Some ſmall rounded maſſes of ſerpentine are met with in many parts on the ſea-ſhore, and ſometimes, but rarely, in ploughed grounds. Aſbeſtos has been diſcovered in the lead mine at Northend, and in ſome of the mountains, where it preſents a great variety of appearance, as it ſeems to graduate into different ſubſtances.

Of the ſilicious genus are quartz cryſtals, which are found in the mines of Aldſton-Moor, beautifully tranſparent, and of various forms and colours: ſome of the yellow kind are but little inferior in brilliancy to the Brazilian topaz. Garnets are not unfrequently found in micaceous ſtones; and ſome beautiful ſmall ones have been met with in the neighbourhood of Keſwick. Cornelians of various tints, but principally of different ſhades of red, are often diſcovered on the ſea-ſhore, and near the ſurface of the earth in many other places. Jaſpers of different colours, often veined, clouded, and ſpotted, are generally met with in beds of rivers, and on or near the ſurface of the ground. Many ſubſtances of the argillaceous genus are found in different parts of the county. Trap, whinſtone, and toadſtone, exiſt almoſt every where; the two latter generally in detached pieces on the ſurface. Schiſtus, of ſeveral varieties of colour, is found in immenſe ſtrata in many parts; and ſchiſtoſe clay, frequently of a tabulated ſtructure, reſembling the leaves of a book, is met with in moſt coal-mines, at Giſland, Keſwick, and various other places. Terra-porcellanea, or porcelain clay, the *kaolin* of the Chineſe, is found at Barrock, near Nebſteps: it is of a white and cream colour, moſtly friable, and duſty; it contains minute particles of ſhining ſilvery mica. On the banks of Ullſwater, tripoli is frequently diſcovered in rounded lumps, of a greeniſh colour, in gravel beds ſometimes, and in coarſe martial clays. Foſſil, or pit-coal, is found in many parts of the county, and of very different qualities. It is met with at various places along the eaſtern mountains; but is eaſieſt of acceſs, and in the greateſt abundance, on Talkin and Tindale Fells, whence Carliſle, Penrith, and

Brampton are chiefly ſupplied. On the weſt ſide of the river Caldew, near Calbeck, and thence to Maryport, Workington, and Whitehaven, it exiſts in great abundance; and many coal-mines are conſtantly at work in this diſtrict, and particularly at Whitehaven. Some very large pits have alſo been opened at Workington and Tindale Fell, near Brampton. Thin layers of jet are ſometimes found in the rocks on the Irthing, in ſmall detached pieces in the bed of that river, on the ſea-ſhore, and near the ſurface of the earth in other places. Wallerius, and other eminent chemiſts, have ſuppoſed it to be aſphaltum, condenſed and hardened by length of time. It bears a fine poliſh; and is frequently worked into toys, bracelets, boxes, buttons, and other articles. The famous black-lead, or wadd mines, are ſituated at the head of Borrowdale, in a place extremely difficult of acceſs, and, for the riches and qualities of the ſubſtance, are unequalled by any in the world. The mines lie to the eaſt of a very ſteep mountain, which forms the weſt ſide of the vale of Stomathwaite. There are two workings: the lower one is about 340 yards above the level of the ſea, and its perpendicular depth about 105 yards; the upper one is nearly 390 yards above the ſea, and its depth about 30. The ſtrata of the mountain are very irregular, and broken; and the black-lead appears to have been formed in the fiſſures. The mineral itſelf does not exiſt in regular ſtrata, but is found in irregular maſſes. It is deſcribed as lying in the mine in form reſembling a tree, having a body or root, and veins or branches ſpreading from it in different directions: the root or body is the fineſt black-lead, and the branches the worſt; growing proportionally more inferior, as they become diſtant from the parent ſtem. The veins, or branches, ſometimes ſhoot out to the ſurface of the ground; yet theſe indications are very rare. The black-lead is generally embedded in a blue rock, which is not unfrequently ſtained as black as the mineral itſelf to the depth of two or three feet; ſometimes there is a wet ſludge between the rock and the black-lead; at others it is found in ſops, or lumps, in a body without branches. In the deepeſt mine, the black-lead lies in two veins, croſſing each other; the main body, and richeſt in quality, being at the point of interſection: theſe veins fall perpendicularly to the depth of 40 fathoms. The blue ſtone, where the black-lead is commonly found, has often a ſtratum of hard granite above it. Quartz cryſtals are frequently diſcovered in the working. The country in the immediate vicinity of the wadd mines has been deſcribed by a native of Cumberland (Mr. George Smith), as full of cataracts and rivers, that are precipitated from the craggs with an alarming noiſe; and the ſummit of the mountain itſelf, in whoſe bowels this valuable mineral is produced, has been depicted by the ſame gentleman as truly terrifying. "Not a herb was to be ſeen but wild ſavine, growing in the interſtices of the naked rocks; while the horrid projection of vaſt promontories, the vicinity of the clouds, the thunder of the exploſions in the ſlate quarries, the diſtance of the plain below, and the mountains heaped on mountains that were piled around us, deſolate and waſte, like the ruins of a world which we had ſurvived,' excited ſuch ideas of horror as are not to be expreſſed." The value of this ſubſtance, and the ſingular fraud of an owner of a contiguous part of the mountain, who ſecretly ſunk a ſhaft, and opened a paſſage diagonally to the mine, occaſioned an act of parliament to be made in the reign of George II. to prevent its being ſtolen, by ſubjecting the criminal to the ſame puniſhment as for felony. In this act there is a recital, that black-lead hath been diſcovered in one mountain or ridge of hills only in this kingdom; and that "it hath been found, by experience, to be neceſſary in the caſting of bomb-ſhells, round-ſhot, and cannon-balls." The chief uſe to which it is now applied is drawing; and the lead of ſome pencils made at Keſwick is of ſo very fine a texture, that it bears a point nearly as ſharp as that of a needle. Some aſſert that it may be uſed medicinally, to eaſe the pains of the gravel, ſtone, ſtrangury, and colic.

The principal metallic ſubſtances of Cumberland are lead, copper, and iron ores. The lead mines are chiefly in Aldſton-Moor, on the ſouth-eaſt borders of the county, where about 1100 men are employed, and clear to the owners upwards of 16,000*l. per annum.* In working ſome of theſe mines, the miners frequently meet with large breaks in the rock, like grottoes, wholly encruſted with the moſt beautiful ſpar, which, on entering, has the richeſt appearance imaginable. The whole cavern, by the light of a candle, reflected from a thouſand points, appears as if beſpangled with gold, ſilver, and diamonds. Theſe internal openings are generally cloſed up as ſoon as found; the ſpar they contain being a great temptation to the workmen to neglect the ſervice of their employers, as they could obtain more by gathering and ſelling ſpar than by their own buſineſs. Galena is found, in all its varieties, in the mines in the vicinity of Aldſton, Keſwick, and Caldbeck; and it not unfrequently contains a conſiderable portion of ſilver. The lead ores, in the mines of Aldſton-Moor, are found lying in cracks or fiſſures. Theſe fiſſures, though commonly nearly perpendicular, are never wholly ſo; and in whatever direction they are found, they always incline downwards from that ſide where the ſtrata are higheſt: thus, in a vein from north to ſouth, if the ſtrata ſhould be raiſed higher on the ſouth ſide the fiſſure than on the north ſide, its inclination will then be from the ſouth downwards to the north. The copper ores are commonly combined with ſulphur, and generally contain both iron and arſenic. The moſt conſiderable copper mines are near Caldbeck, at Heſket New-Market in Borrowdale, and at Newlands in the neighbourhood of Keſwick, where the celebrated mine of goldſcarp is ſituated; from which, by the old workings, and written documents, it appears that immenſe quantities of copper have formerly been obtained. Specimens of copper ores have been found in the mountains named Hard-knot and Wrynoſe, and at ſome other places. Ochreous iron ores, reſembling thoſe called by Mr. Kirwan highland argillaceous ores, are very commonly met with either on or near the ſurface, in moſt parts of the county, eſpecially in moory ſoils, and where the under-ſtratum is a coarſe martial clay. They appear to have been depoſited by water, as they are generally found concreted with ſmall ſtones, roots, and other ſubſtances. In the pariſh of Egremont, at a place called Crowgarth, is the moſt ſingular mine of iron ore ſuppoſed to be in Great Britain. It lies in the earth, at the depth of 12 fathoms; and the thickneſs of the band of ore, which is hard ſolid metal, is between 24 and 25 feet. It was never known to be much wrought till the years 1784 and 1785, when it was more generally opened; and ſo great has been the demand for it, at Carron foundery in Scotland, and ſome other places, that, in 1791 and 1792, the annual exportation was 20,000 tons and upwards. At Langnor, between Whitehaven and Egremont, many varieties of the hæmatites are found, and ſometimes, from their colour and ſhape, are called kidney ore. Native Pruſſian blue is ſometimes found in the peat-moſs of this county, and in clay, particularly that of Etterby-ſcar, near Carliſle; its qualities, however, are different from the artificial.

Among the ſemi-metals, blende, pſeudo-galena, or black-jack, is met with in the greateſt plenty. Its forms and colours are very different: ſome is bluiſh, reſembling galena;

black, or greeniſh-black, like pitch; of a glaſſy ſhining ſurface, often cryſtallized, in irregular pyramids, and other irregular figures; ſometimes containing ſilver, arſenic, and other ſubſtances. Oxyd of zinc has been found at Borrowdale and Ouſley. A mine of cobalt was diſcovered about ten years ſince, in the pariſh of Croſtwaite, near Cowdale, about four miles from Keſwick; but has hitherto been little regarded. Antimony has been found at Baſſenthwaite; and in the ſtratum under the coal at Tindale Fell, oxyd of mangaueſe, tinged and intermixed with pyrites and mica: it has alſo been diſcovered at Caldbeck.

This county abounds with lakes, ſome of which will be hereafter deſcribed under Lake. The principal are known by the names of Ulls-water, which occupies an area of about 9 miles in its greateſt length, by about three-quarters of a mile, on an average breadth; Thirlmere, or Leathes-water, a narrow irregular ſheet of water, about 3 miles in length, ſkirts the immenſe baſe of Helvellyn; Derwent-water, or Keſwick lake, is rather of an oval figure, and extends nearly 3 miles in length, and about half ſo much in breadth; Baſſenthwaite-water, or Broad-water, which is nearly 3 miles north of Keſwick lake, abounds with beautiful ſcenery, and is 4 miles long, and 1 in its greateſt breadth; Over-water, in a barren ſituation between Binſey and Caldbeck-fells, is about half a mile in length, and in breadth ſomewhat more than a quarter of a mile; Lowes-water, beautifully ſituated near the north-weſtern extremity of the mountains above Mellbreak, is about a mile long, and a quarter broad, and, contrary to all the others, diſcharges its waters at the ſouthern end; Crummock-water expands its pellucid boſom beneath ſome lofty mountains, and extends nearly 4 miles in length, and half a mile in breadth; Buttermere-water, about a mile ſouth of Crummock-water, from which it is ſeparated by a luxuriant vale, is about a mile and half long, and half a mile broad, into which numerous torrents pour down from the mountains, one of the roaring cataracts falling between four and five hundred yards; Ennerdale-water ſpreads among the mountains near to Whitehaven, and guarded, on every ſide but the weſt, with craggy and almoſt impaſſable heights, poſſeſſes a ſpace of about 2 miles and half in length, its greateſt breadth being about three quarters of a mile; Waſt-water expands its cryſtal ſurface in the boſom of Waſtdale, to the length of 3 miles, and breadth, in the wideſt part, of three quarters of a mile; Burn moortarn, ſeated among the wildeſt mountains at the head of Miterdale, covers about 250 acres; Devock-water occupies about 300 acres, amongſt the hills ſouth-eaſt of Ravenglaſs; Talkin-tarn and Tindale-tarn poſſeſs about 40 or 50 acres each, on the moors ſouth-eaſt of Brampton; and Turnwadling ſpreads its waters over 100 acres, on a barren common, 1 mile weſt from the river Eden, at Armathwaite.

The mountains of Cumberland are exceedingly numerous, and many of them of immenſe elevation, and ſingular ſtructure. They enter into the compoſition of almoſt every view; and either by their ſublime heights, their romantic forms, the dignified grandeur of their aſpects, the immenſity of the rocky maſſes that compoſe them, or the wild, awful, and impoſing majeſty of their appearance, are well calculated to give birth to intereſting emotions.

The rivers and ſmaller ſtreams of this county are very numerous. The principal are the Eden, the Eamont, the Duddon, the Ehen, the Derwent, the Greata, the Cocker, the Ellen, the Waver, the Wampool, the Caldew, the Peteril, the Eſk, the Liddal, the Line or Leven, the Irthing, and the Gelt. Hutchinſon's Hiſtory of the County of Cumberland, 2 vols, 4to. Houſeman's Topographical Deſcription of Cumberland, &c. 8vo.

Cupel

CUPEL, or Cupellation, in *Chemistry*. Cupellation is a process employed in the assay of gold and silver, by which the alloy, or base metal, with which any sample of the noble metals may be mixed, is separated, and its proportion ascertained. The rationale of this process is founded on the following facts.

Of all the metals hitherto discovered, three alone (namely, gold, silver, and platina,) are incapable of being oxydated or rusted by mere exposure to air, either when solid or in fusion; and hence gold and silver anciently acquired the name of *noble* metals. All other metals tarnish and are oxydated when kept in fusion in open vessels, (some with extreme ease, others not without difficulty,) so that by constantly removing the skin of oxyd as it forms, and exposing fresh surfaces to the air, the whole metal may be finally changed into oxyd. Hence when a mixture of a *noble* and a *base* metal (or in other words, of a metal unchanged, and of one oxydable by fusion,) are melted and exposed to air, the base metal gradually changes to an oxyd, and is thrown off in the form of coloured scales or glassy pellicles, and the noble metal remains unaltered. This separation, however, is not in all cases equally accurate, for where the *alloy* or base metal is not very easily oxydable, and where the proportion of the alloy to the noble metal is but small, the affinity which the latter exercises towards the former is so great, and increases so much with the decreasing proportion of the alloy, as to protect it compleatly from any further action of the air, and to preserve it in the metallic state. Thus, for example, if a mixture of equal parts of silver and copper are kept in fusion in an open vessel, a crust of brown oxyd of copper readily forms, which, if removed, is succeeded by other crusts that continue to be produced, but with increasing difficulty, till the copper is only about a twelfth of the mass; but after this point scarcely any continuance of heat will compleat the oxydation of the remaining portion of the alloy.

The same, however, does not take with lead when alloyed with silver, for on fusing the mixed mass the lead speedily oxydates on the surface, and at the same time vitrifies into litharge, and if this is removed, every particle of lead may be thus extracted, and the silver alone left behind perfectly pure.

Now it is found that when a triple alloy of silver, copper, and lead, is mixed together (the quantity of lead being several times greater than that of the copper) the oxydability of the copper is so much increased by the presence of the lead, owing to the affinity of the two oxyds, and the solubility of the copper oxyd in that of the lead when in fusion, that the silver is no longer able to protect any portion of the copper from oxydation, and the whole alloy is removed from the noble metal, even to the last sensible particle.

This, therefore, is the principle on which the process of cupellation is founded, namely, that of mixing the alloyed noble metal with a considerable portion of lead, exposing the whole to a melting heat with access of air, and thus converting to an oxyd both the lead and every other base metal present in the mass, till the noble metal is left behind perfectly pure.

This process is performed both in the large way in extracting silver from the ore and refining it, and in the small way in assaying those mixtures of gold and silver with different alloys which are used in such large quantities for plate, coin, &c. &c. The former, indeed, is technically called refining, and the latter only cupellation, and some little variation in the management of each takes place, but the principle in both is precisely the same.

Cupellation is usually performed in a furnace contrived for the purpose, and capable of giving a pretty intense heat. The body of the furnace is a hollow four-sided prism, in the middle of which is fixed an earthen vessel called a muffle, of an oven shape, vaulted at top, entirely open at one end, and with a flat floor at bottom. The open end of the muffle comes in close contact with a correspondending hole in the side of the furnace, and is luted to it, and the closed end projects as far as the centre of the furnace. By this contrivance the muffle is heated by the fuel round it, whilst not a particle of the burning charcoal can fall into its cavity, and a gradation of heat is also obtained within it, being the most intense at the closed end which is in the centre of the fire, and the least at the open end contiguous with the hole in the side of the furnace. The cavity of the muffle being large in comparison with the vessels which it is to contain, a considerable body of heated air is constantly circulating over the melted metal, which is necessary to keep up the constant oxydation of the lead and alloy on which the process of cupellation depends.

But as it would be nearly impracticable to keep up the

requisite heat within the muffle, whilst one side was entirely open to the external air, a small vestibule or shelf of iron is made to project a few inches from this opening, on which several long cylinders of charcoal are heaped up whilst the process is going on, which take fire by touching the end of the red-hot muffle, and partially block up the opening, so as fully to heat the outer air in passing to it.

The melted metal is contained in small earthen vessels called *cupels*, which are small solid cubes or cylinders about an inch or an inch and a half across, and with a small depression at top which lodges the melted globule. The cupels may be made of any earth of little cohesion, such as the ashes left after the lixiviation of the saline residue of burnt wood, which are much used in *refining*; but for *cupellation*, or assaying in the small quantities, the cupels are made entirely of bone-ash or phosphat of lime, which possesses the qualities of porosity and infusibility in an eminent degree. This is ground to a fine powder, then a little moistened with water, and the mass (which possesses scarcely any cohesion) is forcibly struck into an iron or a brass mould, where it takes the requisite form, and on drying becomes solid enough for use. The cupels are so small that several of them may be ranged side by side on the floor of the muffle, and they are so extremely porous that the fused oxyd of lead sinks into their substance with as much ease as water into a lump of chalk, but all of the globule of metal that remains in the metallic state is detained in the little cavity on their surface. It should be observed, that the cupels cannot absorb more than their own weight of litharge at the utmost, so that the quantity of metal used and the required proportion of lead must be regulated accordingly.

Experience has shewn the extreme accuracy and nicety of manipulation requisite to conduct cupellation with uniform exactness, and yet there is no process in which accuracy is of more real importance, since the quantities operated on are at most only a few grains, which are taken as samples of the purity and consequent value of very large masses of gold and silver. Hence, too, scales and weights of uncommon delicacy are required.

Cupellation of Silver.

For the assay of silver a clean piece of the metal is taken, which is not more than 36 grains, and less if the alloy appears abundant, is laminated, and weighed with the utmost care. It is then wrapped up in a piece of sheet-lead of the proper weight, or both the silver and lead are folded in paper ready for use. The purity of the lead is important; for all lead naturally contains a little silver, which, if not removed, might make a sensible error in the assay. The lead is, therefore, always revived from litharge; in which state it is remarkably pure, and contains no more than $\frac{1}{4}$ grain of silver in the pound, which quantity may be entirely neglected.

The mode of proportioning the quantity of lead to the estimated quantity of alloy in the silver will be presently noticed.

The fire being kindled, and the floor of the muffle sprinkled with chalk, to prevent the cupels from being glued to it in the process, the muffle and empty cupels are first made fully red-hot, and the cylinders of charcoal are put against the open end of the muffle, as already described. The silver and lead are then dropped into the cupel, and the charcoal replaced. The metals immediately melt together; and, when red-hot, the following appearances take place. The melted globule begins to send off dense fumes, which rise to the roof of the muffle, and at the same time a thin stream of red fused matter is seen constantly flowing down the sides of the globule to the surface of the cupel, through which it sinks. This fume is the oxyd of lead evaporated by the heat, and the stream of fused matter is the melted litharge, together with the copper or other alloy of the silver which is thus extracted from it. In proportion to the intensity of the heat are the density of the fume, the violence with which it is given off, and the rapidity with which the melted oxyd *circulates*, as it is termed, or falls down the sides of the metal. As the cupellation advances, the melted globule becomes rounder, and its surface more streaky, till, in about fifteen or twenty minutes, according to circumstances, all the lead and alloy are vitrified and absorbed by the cupel, the last portions of litharge collect in large bright streaks, which disappear with great rapidity, shewing the melted metal beneath bright with iridescent colours, which suddenly after becomes opake, and exquisitely white and brilliant, exhibiting the clean surface of pure melted silver. This last appearance is called the *lightning* of the metal, and it is highly beautiful, as if a red curtain was suddenly withdrawn from the metal. The operation is now finished, and the cupel is drawn forwards to the open side of the muffle, that it may cool gradually before it is removed; for, if it were suddenly fixed, the globule is apt to shoot into an arborescent surface in the act of congealing, by which small particles are thrown out of the cupel and lost, and the assay is spoiled.

In the cupellations made at the mint assay-office, two assays are made of the same metal, and no sensible difference between the weight of the two buttons is allowed to pass, as ascertained by scales, that turn with the $\frac{1}{1000}$th of a grain.

The process is considered as well performed when the button of silver adheres but slightly to the cupel; when its shape is very considerably globular, and not flattened at the margin; when it is quite white, clean and brilliant, and not fouled or spotted with any remaining litharge. In this state of purity, the surface of the button is never quite smooth, but is somewhat scaly or striated, the effect of a very strong tendency to crystallization, which perfectly pure silver possesses, but is not found in plate or alloyed metal. Under the microscope, this irregularity of surface is still more observable, and the scales seem to incline to a pentagonal form.

Where the alloy of the silver is only copper, as is usually the case, the cupel round the button is stained of a brown grey.

The management of the fire in cupellation is of great importance. If it is so intense that the cupel can scarcely be distinguished from the muffle, and the fume of litharge can hardly be discerned through the dazzling heat, not only much of the lead is volatilized to mere waste, but even a portion of the silver is carried off along with it, which renders the assay inaccurate. Even silver alone, and in the greatest purity, may be evaporated by intense heat as M. Tillet (an ingenious French chemist, and master of the mint at Paris) found, by an experiment, in which a button of pure silver was intensely heated for two hours, and had lost thereby no less than $\frac{1}{10}$ of its weight. If one vessel is inverted over another that contains the silver, in this case the inside of the upper one is found studded with minute globules of silver, when viewed through a common lens. On the other hand, when the fire is too slack in cupellation, the litharge is not fully melted as it forms, and, therefore, is not absorbed by the cupel, but lies on the surface as a red scoria, and the circulation is very sluggish. The proper medium of heat is, when every thing within the muffle is fully red-hot; when

the fume of litharge is abundant, and viſibly riſes to the top; and when the circulation goes on rapidly, and the button continues very globular. Towards the end of the proceſs, the heat ſhould be increaſed as the button, by the conſtant abſtraction of the lead, becomes conſtantly leſs eaſily fuſible.

It has been already mentioned, that in cupellation all the alloy of the ſilver is carried down into the cupel along with, and diſſolved in the litharge, provided lead enough be uſed. But it was alſo found by M. Tillet, that a ſmall portion of the ſilver is at the ſame time carried down with the lead; ſo that, when perfectly pure ſilver is cupelled with lead of known purity, the button of ſilver left after the proceſs never weighs quite ſo much as before, even though the heat employed is ſo moderate as not to volatilize any of the ſilver. As a proof that ſome of the ſilver is carried down into the cupel, M. Tillet ground this veſſel to powder, and fuſed it with a reducing flux, whereby he recovered nearly all the lead that had been uſed, and which now contained ten times as much ſilver as its natural retent of this noble metal, nine tenths of which, therefore, muſt have been derived from the button of ſilver during cupellation. Accordingly, on cupelling this lead, *per ſe*, it left behind all this exceſs of ſilver, and now only carried down its natural retent, which amounts to about $\frac{1}{1152}$, or half a grain in a pound French.

It remains to give the proportions of lead to alloy, which have been found the moſt uſeful in cupellation, and the method of eſtimating the quantity of alloy previous to this operation, with ſufficient exactneſs to guide the artiſt. The ancient aſſayers uſed for this purpoſe ſmall ſlips or bars of metal, made with pure ſilver and copper, in known proportions, in a regularly increaſing ſeries, from the leaſt to the greateſt quantity of alloy uſually required. Theſe ſets of bars were called *touch-needles;* and, by comparing the ſilver to be aſſayed with theſe needles, in colour, tenacity, and other external marks, its proportion of alloy was gueſſed at with ſufficient accuracy to determine the quantity of lead required in the cupellation. Theſe needles are now, however, almoſt totally diſuſed in ſilver-aſſaying, as an experienced aſſayer is able to judge of the fineneſs of ſilver, with quite ſufficient accuracy, by the eaſe with which it is cut, the colour and grain of the freſh-cut ſurface, the malleability, the appearances on being heated red-hot, and other tokens.

The proportion of alloy (if copper) to the ſilver being found with ſufficient exactneſs, that of the lead is thus eſtimated. Copper, when taken by itſelf, requires from 10 to 14 times its weight of lead for complete ſcorification on the cupel. But all admixtures of fine metal tend to protect the copper from the action of the litharge, the more, in proportion to the quantity of fine metal. Thus, when one part of copper is mixed with three of ſilver, no leſs than 40 parts of lead are required; and one part of copper with 11 of ſilver require 72 parts of lead. It ſhould be obſerved, however, that a conſiderable difference in the reſpective proportions of lead to copper is obſerved by different aſſayers, though the general principle of increaſing the lead in proportion to the quantity of fine metal is indiſputable.

The following table will ſhew ſome of the proportions uſed in the French mint, as given by M. Tillet, and alſo others uſed by the German chemiſts, as given by Gren:

pper.		Silver.		Lead.
1	with	0	requires	10.
1	——	$\frac{1}{15}$	——	17 Ger.
1	——	$\frac{1}{11}$	——	28 Fr.
1	——	$\frac{1}{3}$	——	20 Ger.
1	——	$\frac{1}{3}$	——	29 Fr.
Copper.		Silver.		Lead.
	with	$\frac{1}{2}$	requires	30 Fr.
	——	1	——	32 Fr.
	——	2	——	36 Fr.
	——	3	——	40 Fr. and Ger.
	——	4	——	56 Ger.
	——	5	——	48 Fr.
	——	7	——	64 Ger.
	——	11	——	72 Fr.
	——	15	——	96 Ger.
1	——	23	——	96 Fr.
1	——	30	——	128 Ger.

Cupellation of Gold.

The proceſs of cupellation is the ſame for gold as for ſilver, the alloy, in both inſtances, being worked off by lead; but ſeveral curious circumſtances take place with mixtures of gold with other metals, which are not eaſily explicable. When pure gold is mixed with lead and cupelled, the whole of the lead is not ſeparated, as it is with pure ſilver, but a ſmall portion remains combined with the gold ſufficient to impair its colour and ductility. If, beſides gold and lead, the mixture contains copper to the amount of $\frac{1}{12}$ of the gold, the whole of the lead will now be ſeparated in cupellation, but almoſt the whole of the copper will remain. If, in addition to the above ingredients, the alloy contains a ſomewhat greater proportion of ſilver than it does of copper, this latter is ſeparated by cupellation, but a little of the lead remains. But if the amount of ſilver equals or exceeds that of the gold, all the lead and copper are ſeparated, and only the gold and ſilver remain.

As, therefore, the object of cupellation is to ſeparate the whole of the alloy of baſe metal, it is neceſſary, in aſſaying gold, to add firſt a very conſiderable quantity of ſilver, then to work off the copper, and other baſe metal, by lead on the cupel, and afterwards to ſeparate the gold and ſilver by the proceſs of *parting,* as it is called, by means of nitric acid.

The aſſay of gold, therefore, is more complicated than that of ſilver, and requires the intervention of this latter metal. The quantity of ſilver muſt, as already mentioned, be at leaſt equal to that of the gold, to enable the lead to extract all the copper in cupellation; but, in fact, the ſilver is generally three times as much as the gold, otherwiſe, though all the copper may be removed by a much leſs proportion, the ſubſequent ſeparation of the ſilver from the gold by nitric acid cannot well take place. For it is found that, unleſs the ſilver be in this large quantity, the gold, which is not itſelf touched by the nitric acid, alſo protects a portion of the ſilver from the acid, and the ſeparation is not complete.

The cupellation of gold therefore is conducted in the following manner: the quantity of copper or other alloy preſent, being firſt eſtimated as accurately as poſſible in the way that will be preſently mentioned, as much fine ſilver is added to the mixture, as will make the gold only a *fourth* of the maſs when the baſe alloy has been removed. If the gold is already alloyed with any ſilver, a proper allowance is of courſe made for the eſtimated quantity. This proportioning of the ſilver to the gold, and melting them together, is called *quartation,* the gold being reduced thereby to one-fourth of the maſs of noble metal. To the mixture the requiſite quantity of lead is then added (which is nearly the ſame as in ſilver aſſaying) and the cupellation is conducted exactly in the ſame manner, only that a higher heat may be be given, as the ſilver in this mixture is not volatilized by a ſtrong fire, as it is in mere ſilver aſſaying. The *lightning*

takes place here alſo when every particle of lead and other baſe metal is removed, and only the gold and ſilver are left on the cupel.

The ſeparation of theſe noble metals by nitric acid, and the exact proceſs of parting, will be deſcribed under Gold. It may be juſt mentioned, however, that the button is firſt flattened, and then rolled out into a ſmall coil, and then put into a glaſs, and with boiling nitric acid, by which all the ſilver is extracted, and the gold alone is left behind in perfect purity.

The quantity of alloy in any mixture of gold with other metals is eſtimated previous to cupellation, partly by the general appearance (the nature of the alloy being known) and partly by the uſe of the touch-ſtone. In judging by the general appearance alone much advantage may be derived from touch-needles, but the caſe is more complicated here than in ſilver aſſaying, ſince three metals at leaſt are concerned in gold aſſaying, namely, gold, ſilver, and copper. Therefore if theſe needles are uſed, there muſt be ſeveral ſets of them adapted to the nature of the alloy.

The trial by the touchſtone is another ſimple and very ingenious method of forming ſome eſtimate of the proportion of alloy in any gold mixture. For this purpoſe the piece of metal to be tried is rubbed hard upon a piece of black baſalt or black pottery, ſo as to make a broad bright metallic ſtreak by the abraſion of ſome of the metal. This ſhews at once the true colour of the alloy, which may alſo be compared with another ſtreak made by a touch-needle beſide it. A drop or two of nitric acid is then ſpread upon the ſtreak, and after remaining about ten ſeconds, it is waſhed off, and the effect obſerved. If the ſtreak preſerves its golden colour unaltered, the metal is judged to have a certain degree of fineneſs, as gold is inſoluble in this acid; if it looks red, dull, and coppery, it is leſs fine; if the ſtreak is almoſt entirely effaced, the metal contains very little gold; and thus by the aſſiſtance of this acid, an experienced aſſayer will come at a ſufficiently accurate knowledge of the quantity of alloy to guide him in the addition of lead and ſilver in the cupellation. It is found however that though pure nitric acid will readily diſſolve copper ſingly, it will not act ſenſibly on this metal, when in mixture with twice its weight of gold, ſo effectually does the gold protect the copper againſt this powerful acid. But if a ſmall proportion of muriatic acid is added, the copper will be diſſolved when the gold is not more than three-fourths of the mixture, and thus the power of this teſt is much extended. Vauquelin, in his "Manuel de l'Eſſayeur," recommends for this purpoſe an acid compoſed of 98 parts of nitric acid of 1.34 ſp. g., 2 parts of muriatic acid of 1.173 ſp. gr., and 25 parts of water. This does indeed compoſe a nitro-muriatic acid, which is the proper ſolvent for gold, but the gold on the touch-ſtone is not in this caſe ſenſibly acted on, owing to the ſhortneſs of the application, and the very ſmall proportion of muriatic acid.

Touching is alſo of great uſe in determining the value of wrought trinkets which cannot ſpare ſo much as 8 or 10 grains for a regular aſſay.

Cupellation of Alloys of Platina.

On account of the great ſpecific gravity of platina, it was long apprehended that gold might be adulterated with it to a conſiderable degree without being eaſily detected, for as platina is equally unoxydable by air as gold and ſilver, it cannot be ſcorified by lead on cupel, and being inſoluble in nitric acid its ſeparation from gold is not readily effected. It is not difficult, however, to detect this metal when mixed with gold or ſilver even in very ſmall proportion.

Gold alloyed with ſo little as one *per cent.* of platina and cupelled in the uſual way, with thrice its weight of ſilver, differs from gold and ſilver alone in requiring a much greater heat for cupellation and compleat fuſion of the button; otherwiſe, when all the lead is worked off, the button remains flat, like a piece of money, and its ſurface knotty. Even when the button is well fuſed its edges are much thicker, and rounder than in common gold aſſays, its colour duller, and eſpecially it appears remarkably cryſtallized on its ſurface. Alſo in cupellation, when the laſt portions of lead are worked off, the button appears paſty, ſcarcely irideſcent, and does not lighten, or become ſuddenly brilliant as ſilver and gold alone, or gold and ſilver do.

Silver bears alloying with platina better than gold does; but this is never done fraudulently. When the platina does not exceed 5 *per cent.* of the ſilver, it works eaſily on the cupel, but the *lightning* is leſs obſervable than with pure ſilver, and, in particular, the property of cryſtallizing is ſtill more conſpicuous. When the platina amounts to a quarter of the mixture, the button or cupel flattens, and becomes paſty even before all the lead is run off, and its ſurface ſhoots up into knobs which, when ſeen by a magnifier, appear cluſters of cryſtalline points.

Some remarkable occurrences take place with the alloys of gold or ſilver with platina, when treated with nitric acid, which will be mentioned under that metal.

Currying

CURRYING is the art of dreſſing cow-hides, calves-ſkins, ſeal-ſkins, &c. principally for ſhoes; and this is done either upon the fleſh or the grain.

In dreſſing leather for ſhoes on the fleſh, the firſt operation is ſoaking the leather in water, until it be thoroughly wet; then the fleſh-ſide is ſhaved on a beam, about ſeven or eight inches broad, with a knife of a peculiar conſtruction, to a proper ſubſtance, according to the cuſtom of the country, and the uſes to which it is to be applied. This is one of the moſt curious and laborious operations in the whole myſtery of currying. The knife uſed for this purpoſe is of a rectangular form, with two handles, one at each end, and a double edge. They are manufactured at Cirenceſter, and compoſed of iron and ſteel; the edge is given to them by rubbing them on a flat ſtone of a ſharp gritty ſubſtance, till it comes to a kind of wire; this wire is taken off by a fine ſtone; and the edge is then turned to a kind of groove wire by a piece of ſteel, in form of a bodkin, which ſteel is uſed to renew the edge in the operation.

After the leather is properly ſhaved, it is thrown into the water again, and ſcoured upon a board or ſtone commonly appropriated to that uſe. Scouring is performed by rubbing the grain or hair-ſide with a piece of pumice-ſtone, or with ſome other ſtone of a good grit, not unlike in thickneſs and ſhape to the ſlate with which ſome houſes are covered. Theſe ſtones force out of the leather a white ſort of ſubſtance called the bloom, produced by the oak-bark in tanning. The hide or ſkin is then conveyed to the ſhade or drying-place where the oily ſubſtances are applied, termed ſtuffing or dubbing; the oil uſed for this purpoſe is prepared by the oil leather-dreſſers, by boiling ſheep-ſkins or doe-ſkins in cod-oil. This is put on both ſides of the leather, but in a greater and thicker quantity on the fleſh than on the grain or hair-ſide.

Thus we have purſued the currying of leather in its wet ſtate, and through its firſt ſtage, commonly called getting out.

When it is thoroughly dry, an inſtrument with teeth on the under-ſide, called a graining board, is firſt applied to the fleſh-ſide, which is termed graining; then to the grain-ſide, called bruiſing; the whole of this operation is intended to ſoften the piece of leather to which it is applied. Whitening or paring ſucceeds, which is performed with a fine edge of the knife already deſcribed, and uſed in taking off the greaſe from the fleſh. It is then boarded up or grained again, by applying the graining board, firſt to the grain and then to the fleſh.

It is now fit for waxing, which begins with colouring. This is performed by rubbing with a bruſh dipped in a compoſition of oil and lamp-black on the fleſh, till it be thoroughly black; it is then ſized, called black ſizing, with a bruſh or ſpunge, dried, tallowed with a woollen cloth; and ſlicked upon the fleſh with a broad ſmooth piece of glaſs, ſized again with a ſpunge; and when dry this ſort of leather, called waxed or black on the fleſh, is curried.

Currying leather on the hair or grain-ſide, termed black on the grain, is the ſame in the firſt operation with that dreſt on the fleſh, till it is ſcoured. Then the firſt black is applied to it, while wet; which black is a ſolution of copperas in fair water, or in the water in which the ſkins, as they come from the tanner, have been ſoaked; this is firſt put upon the grain, after it has been rubbed with a ſtone; then rubbed over with a bruſh dipped in ſtale urine; ſlicked out with an iron ſlicker, in order to make the grain come out as fine as poſſible; and then ſtuffed, in the manner already deſcribed among the firſt operations of currying; and when dry it is ſeaſoned, *i. e.* rubbed over with a bruſh dipped in copperas water on the grain, till it be perfectly black; then ſlicked with a ſtone of a good grit, to take out the wrinkles and coarſe grain as much as poſſible: after this the grain is raiſed with a fine graining board, by turning the ſkin or piece of leather in various directions; and when a little dried, it is bruiſed in order to ſoften it. When it is thoroughly dry it is whitened, bruiſed again, and grained in two or three different ways; and when oiled upon the grain with a mixture of oil and tallow, it is finiſhed.

Bull and cow-hides are ſometimes curried for the uſe of ſadlers and collar-makers; but the principal operations are much the ſame as thoſe we have already deſcribed. It ſhould, however, be obſerved, that only a ſmall portion of fleſh is taken from hides deſigned for theſe purpoſes. Hides for the roofs of coaches, &c. are ſhaved nearly as thin as ſhoe-hides, and blacked on the grain.

Cutlery

CUTLERY. Under this head we shall comprise the articles knives, forks, razors, and sciffors. They are all either made of fteel or of iron, with fteel to form the edge.

Three kinds of fteel are made ufe of in the manufacture of different articles of cutlery, *viz.* common fteel, fhear-fteel, and caft-fteel; thefe different kinds are made from what is termed bliftered fteel, which has hitherto been obtained of good quality only from certain kinds of bar iron brought from Sweden and Ruffia.

The bar iron is ftratified with powdered charcoal in a furnace termed a converting furnace, within a recefs termed a pot, from 7 to 14 feet long, 3 feet broad, and 2½ feet deep, the whole covered clofe up with a mixture of clay and fand, fo as to prevent the accefs of atmofpheric air. A ftrong heat is applied for about 8 days; as foon as the pot is cooled, which is in about 8 days more, the bars are taken out, and the iron is found to be converted into fteel; it always appears bliftered upon the furface, and hence is termed bliftered fteel. When thefe bars are taken to the tilt, and drawn into rods of various dimenfions, it is called common fteel. All the cheaper cutlery are made of this fteel, and alfo all kinds of forks.

When a number of bars of bliftered fteel are laid together, heated to a welding heat in a forge furnace, and drawn down into bars under a forge hammer, they conftitute what is termed fhear fteel. It has received this name from its being made ufe of to make wool fhears. It is alfo termed Newcaftle fteel, from having been firft made at that place.

Shear fteel is exceedingly kind and tough. All the edge tools which require great tenacity without great hardnefs, are made of it, fuch as table-knives, fcythes, plane-irons, &c. It is alfo freer from flaws, on account of the welding heat which has been given to it.

Caft-fteel is formed by melting bliftered fteel in covered crucibles, and pouring it into caft-iron moulds, fo as to form it into ingots: thefe ingots are then taken to the tilt and drawn into rods of fuitable dimenfions. No other than caft-fteel can affume a fine polifh, and hence all the finer articles of cutlery are made of it, fuch as the fineft fciffors, pen-knives, razors, &c.

Formerly caft-fteel could only be worked at a very low heat; it can now be made fo foft as to be welded to iron with the greateft cafe. Its ufe is confequently extended to making very fuperior kinds of chiffels, plane-irons, &c.

Forging of Table Knives.

Two men are generally employed in the forging of table knives, one called the foreman or maker, and the other the ftriker.

The fteel called common fteel is employed in making the very common articles; but for the greateft part of table knives which require a furface free from flaws, fhear-fteel is generally preferred. That part of the knife termed the blade, is firft rudely formed and cut off. It is next welded to a rod of iron about ½ inch fquare, in fuch a manner as to leave as little of the iron part of the blade expofed as

possible. A sufficient quantity of the iron now attached to the blade, is taken off from the rod to form the bolster, or shoulder and the tang.

In order to make the bolster of a given size, and to give it at the same time shape and neatness, it is introduced into a die, and a swage placed upon it; the swage has a few smart blows given it by the striker. This die and swage are by the workmen called prints.

After the tangs and bolster are finished, the blade is heated a second time, and the foreman gives it its proper anvil finish; this operation is termed smithing. The blade is now heated red-hot and plunged perpendicularly into cold water. By this means it becomes hardened. Being thus hardened, it requires to be tempered regularly down to a blue colour: in this state it is ready for the grinder. Forks are generally a distinct branch of manufacture from that of knives, and are purchased of the fork makers by the manufacturers of table knives, in a state fit for receiving the handles.

The rods of steel from which the forks are made, are about $\frac{3}{8}$ths of an inch square. The tang and shank of the fork are first roughly formed. The fork is then cut off, leaving at one end about 1 inch of the square part of the steel. This part is afterwards drawn out flat to about the length of the prongs. The shank and tang are then heated, and a proper form given to them by means of a die and swage. The prongs are afterwards formed at one blow by means of the stamp; this machine is very similar to that used in driving piles, but it is worked by one man. It consists of a large anvil fixed in a block of stone nearly on a level with the ground. To this anvil are attached two rods of iron of considerable thickness fixed 12 inches asunder, perpendicularly to the anvil, and diagonally to each other. These are fastened to the ceiling. The hammer or stamp, about 100 lbs. in weight, having a groove on either side corresponding to the angles of the upright rods, is made to slide freely through its limited range, being conducted by its two iron supporters. A rope is attached to the hammer which goes over a pulley on the floor of the room above, and comes down to the person who works the stamp: two corresponding dies are attached, one to the hammer, and the other to the anvil. That part of the fork intended to form the prongs, is heated to a pretty white heat and placed in the lower die, and the hammer containing the other die, is made to fall upon it from an height of about 7 or 8 feet. This forms the prongs and the middle part of the fork, leaving a very thin substance of steel between each prong, which is afterwards cut out with an appropriate instrument called a flie-press. The forks are now annealed by surrounding a large mass of them with hot coals, so that the whole shall become red-hot. The fire is suffered gradually to die out, and the forks to cool without being disturbed. This process is intended to soften, and by that means to prepare them for filing. The inside of the prongs are then filed, after which they are bent into their proper form and hardened. When hardened, which is effected by heating them red-hot and plunging them into cold water, they are tempered by exposing them to the degree of heat at which grease inflames.

Penknives are generally forged by a single hand with the hammer and the anvil simply. The hammer in this trade is generally light, not exceeding $3\frac{1}{2}$ lbs. The breadth of the face, or the striking part, is about one inch, if broader it would not be convenient for striking so small an object. The principal anvil is about 5 inches, and 10 upon the face, and is provided with a groove into which a smaller anvil is wedged. The smaller anvil is about 2 inches square upon the face. The blade of the knife is first drawn out at the end of the rod of steel, and as much more is cut off along with it as is thought necessary to form the joint. The blade is then taken in a pair of tongs, and heated a second time to finish the joint part, and at the same time to form a temporary tang for the purpose of driving into a small haft used by the grinder. Another heat is taken to give the blade a proper finish. The small recess cal ed the nail hold, used in opening the knife, is made while it is still hot by means of a chissel, which is round on one side, and flat on the other.

Penknives are hardened by heating the blade red-hot and dipping them in water up to the shoulder. They are tempered by laying them side by side, with the back downwards upon a flat iron plate laid upon the fire where they are allowed to remain till they are of a brown or purple colour.

The blades of pocket knives, and all that come under the denomination of spring knives, are made in the same way.

The forging of razors is performed by a foreman and striker as in making table knives.

They are generally made of cast-steel. The rods as they come from the tilt are about $\frac{3}{4}$ inch broad, and of a thickness sufficient for the back of the razor.

There is nothing peculiar in the tools made use of in forging razors: the anvil is a little rounded at the sides which affords the opportunity of making the edge thinner, and saves an immense labour to the grinder.

Razors are hardened and tempered in a similar manner to penknives. They are however left harder, being only let down to yellow or brown colour

The forging of scissors is wholly performed by the hammer, and all the sizes are made by a single hand. The anvil of the scissor-maker weighs about $1\frac{1}{2}$ cwt.; it measures on the face about 4 by 11 inches. It is provided with two gates or grooves for the reception of various little indented tools termed by the workmen bosses; one of these bosses is employed to give proper figure to the shank of the scissors; another for forming that part which has to make the joint; and a third is made use of for giving a proper figure to the upper side of the blade. There is also another anvil placed on the same block containing two or three tools called beak irons, each consisting of an upright stem about 6 inches high, at the top of which projects a horizontal beak; one of these beaks is conical, and is used for extending the bow of the scissors, the other is a segment of a cylinder with the round side upwards containing a recess for giving a proper shape and smoothness to the inside of the bow.

The shank of the scissors is first formed by means of one of the bosses, above described, leaving as much steel at the end as will form the blade. A hole is then punched about a $\frac{1}{4}$ inch in width a little above the shank. The blade is drawn out and finished, and the scissors separated from the rod a little above the hole. It is heated a third time, and the small hole above mentioned is extended upon the beak-irons so as to form the bow. This finishes the forging of scissors. They are promiscuously made in this way without any other guide than the eye, having no regard to their being in pairs. They are next annealed (for the purpose of filing such parts of them as cannot be ground) and afterwards paired.

The very large scissors are made partly of iron, the blades being of steel.

After the forging, the bow and joints, and such shanks as cannot be ground, are filed. The rivet hole is then bored, through which they are to be screwed or riveted together. The common kind of scissors are only hardened up to the joint. They are tempered down to a purple or blue colour. In this state they are taken to the grinder.

Grinding and polishing of Cutlery.

The various processes which come under this denomination are performed by machinery, moving in general by the power of the steam engine or a water wheel.

Grinding wheels or grinding mills are divided into a number of separate rooms; every room contains six places called troughs; each trough consists of a convenience for running a grindstone and a polisher at the same time, which is generally occupied by a man and a boy.

Two of the above troughs are represented in *Plate* I. *Cutlery:* A is a wooden wheel, called a drum, the axis of which runs through the whole length of the room. On the same axis are placed three other drums, one of the same length with the above, and two of half the length. Each of the large drums carries four straps, which give motion to the two stones *c*, *c*, and to the polishers *b* and *e*, by passing round their respective pullies *g*, *g*, *g*, *g*: *d*, *d*, *d*, *d*, are the places where the workmen sit, and as he sits astride for the purpose of leaning over the stone, the seat is termed a horse.

The business of the grinder is generally divided into three stages, viz. grinding, glazing, and polishing.

The grinding is performed upon stones of various qualities and sizes, depending on the articles to be ground. Those exposing much flat surface, such as saws, fenders, &c. require stones of great diameter, while razors whose surface is concave, require to be ground upon stones of very small dimensions. Those articles which require a certain temper, which is the case with most cutting instruments, are mostly ground on a wet stone; for which purpose the stone hangs within the iron trough H, filled with water to such a height that its surface may just touch the face of the stone.

In the manufactories of Sheffield not less than five various qualities of stone are employed. The most valuable of the five is termed the Wickersley stone, from its being brought from a village of that name, about nine miles east of Sheffield.

It is of the sandstone kind, rather firmly indurated, of a compact texture. It appears to consist of very hard silicious particles cemented together with a softer medium. Both in the wet and dry state, it cuts with great facility, and is particularly adapted for grinding razors, penknives, table knives, and the inside of the blade of scissors.

Another very useful stone is termed the whitening stone. It is of a blueish white colour, exceeding the Wickersley stone in hardness, in firmness, and in closeness of texture. It is particularly employed for grinding the outside of the blade of scissors, and other articles requiring great smoothness and neatness of shape.

Forks, and the shanks of some scissors, are ground upon a dry stone, termed the fork-stone. It is a very sharp grit stone of a whitish colour, very similar to that of which millstones are formed. The stones employed for grinding saws and files are of a similar quality with the fork-stone, of a yellowish grey colour.

It is necessary that the stones move with a certain velocity, in order to produce a maximum of effect.

If the velocity be too great, two evils are generally to be expected: the first (which is most to be dreaded) is the breaking of the stone, the second is the stone almost ceasing to cut; this is also the case with drills, files, and other similar instruments; if they move too rapidly over the surface they are cutting, they generate much heat, but do not cut so well.

The surfaces of all stones are contrived to move with about the same velocity. This is effected by means of different sized pulleys. The drums above described are four feet in diameter, and make from 120 to 140 revolutions in a minute, and the pulley on the axis of the stone must be of such diameter as to cause the surface of the stone to move at the rate of from 600 to 700 feet per second.

We cannot wonder at the dreadful effects of the breaking of a stone when we consider the great velocity with which they move. The horse or seat of the workman projects over the centre of the stone, and is secured to a beam of wood on a level with the ground by means of a strong chain. This in some measure secures the workman from those pieces of the stone, which might be projected upwards against the under side of the horse. But as it is quite uncertain what direction the fractured parts may take, the above contrivance is only a partial defence against these shocking accidents. It sometimes happens that the chain is broken, and the man and horse together projected to a considerable distance.

Means have been recently adopted by some of the grinders to prevent, in a great measure, the breaking of stones, which consist in a different method of fastening the stones upon the axis. The old method consists in wedging on the stone by means of wooden wedges. The improved method is to secure the stones to the axis by means of two circular plates, which are screwed firmly against the sides of the stone. By this means the parts of the stone are kept together. On the contrary, when the wedges are employed, a force is constantly exerted to break the stone; this effect is increased when the stones are used wet, from the circumstance of the wood absorbing moisture.

Glazing is a process following that of grinding: it consists in giving that degree of lustre and smoothness to an article which can be effected by means of emery of the various degrees of fineness. The tool on which the glazing is performed, is termed a glazer. It consists of a circular piece of wood, formed of a number of pieces in such a manner that its edge or face may always present the endway of the wood. Were it made otherwise the contraction of the parts would destroy its circular figure. It is fixed upon an iron axis similar to that of the stone: some glazers are covered on the face with leather, others with metal consisting of an alloy of lead and tin; the latter are termed caps. In others the wooden surface above is made use of. Some of the leather-faced glazers, such as are used for forks, table knives, edge tools, and all the coarser polished articles, are first coated with a solution of glue and then covered with emery. The surfaces of the others are prepared for use by first turning the face very true, then filling it with small notches by means of a sharp-ended hammer, and lastly filling up the interstices with a compound of tallow and emery.

The pulley of the glazer is so much less than that of the stone, that its velocity is more than double, being in general at the surface that of 1500 feet in a second. The glazer and its pulley are seen at *e* and *b*.

The process of polishing, consists in giving the most perfect polish to the different articles. Nothing is subjected to this operation but what is made of cast-steel, and has been previously hardened and tempered.

The polisher consists of a circular piece of wood covered with buff leather, the surface of which is covered from time to time, while in use, with the crocus of iron, called also co-leather of vitriol.

The polisher requires to run at a speed much short of that of the stone, or the glazer. Whatever may be its diameter, the surface must not move at a rate exceeding

70 or 80 feet in a second. This diminished velocity is effected by causing its strop to pass over the rounded part of the axis of the drum as shewn at B.

Grinding of Table Knives.

The stones made use of are from 35 to 45 inches in diameter, and about six inches broad upon the face. This stone is a species of sand stone, before termed the Wickersley stone. It is first turned, or raised exceedingly true, and then notched upon the face with a sharp-edged tool to make it cut faster. This species of stone cuts astonishingly fast, and has the peculiar property of not heating to a great degree any substance ground upon it. It is valuable on that account for grinding those articles which have been previously hardened. Table knives are ground first upon this stone, and afterwards upon one of finer texture, called the whitening stone. This prepares them for the glazing. The glazer is about 20 inches diameter and 5 inches broad, covered on the face with thick leather. This leather is thinly coated with glue, and is rolled in a quantity of emery. As soon as the glue is set the glazer is fit for use. It runs upon an iron axis, in the same manner as the stone. The bolster of the knife, when plane, is also ground and glazed in a similar way.

Forks.

The stone on which forks are ground are from 18 to 24 inches in diameter and about $2\frac{1}{4}$ inches broad. It is a very sharp grit, something harder than that last mentioned. The face of the stone is a little rounded, for the purpose of meeting hollow parts, which are observed in all forks. The grinder holds the fork crosswise on the stone, and very dexterously gives it a kind of circular motion; by this means he makes the shank very round. The shank and neck of the prongs are ground upon this stone. The stone being dry, a profusion of sparks is given out, and the fork becomes heated with the great friction, till it is blue. The prongs are afterwards ground upon a wet stone, from 14 to 18 inches diameter and about 7 inches broad. The shank and neck of the prongs are finished upon a glazer of a similar shape to that of the stone on which they are ground; this glazer is of wood covered with leather, and prepared upon the surface with glue and emery, in the same manner as that for table knives. The prongs are finished upon a glazer of the same materials, but flat upon the face, about 8 inches both in diameter and breadth. The insides of the prongs are dressed by means of thin leather straps about 2 inches broad and 18 inches long; they are first coated with glue and then covered over with emery: as soon as the glue is set the strop is introduced between the prongs of the fork, and is drawn backwards and forwards till the part becomes sufficiently clean.

Grinding of Penknives.

The stone made use of for penknives is the Wickersley stone, about 16 or 18 inches in diameter when new, and is worn down to about 9 or 10 inches; the breadth is about $4\frac{1}{2}$ or 5 inches. This stone, as has been before observed, having so little tendency to heat the substances ground upon it, is generally made use of dry for grinding penknives. There are several advantages in grinding upon the dry stone. It does not wear so fast. The edges of the stone are kept sharper and the surface evener; but the great advantage is, that the stone cuts much faster. When the surface of a dry stone becomes clogged with the particles of steel adhering to it, a piece of soft iron is always at hand, which being rubbed over it soon clears it of its incumbrance, and a fresh cutting surface is presented.

All the finer penknives, after being ground the first time, go back to be handled or hafted. The handles are wrapped in paper to keep them from being soiled, and the knives thus hafted are again returned to the grinder. The blades are all slightly ground over again upon a stone kept for the purpose of one determinate size. The flat parts of the blade are next glazed upon a glazer or lap made of lead, and for common articles of wood. After the lap is turned perfectly true, and a number of notches are made in the face; the surface is rubbed over with emery and grease. If it is found to cut too keen it is slightly rubbed over with bees wax. This process would finish the common sort of knives, but the finer blades are afterwards polished upon the polisher already described.

Grinding of Razors.

Razors are generally ground upon the stones which are laid aside by the grinders of penknives and scissors. They take them when about the diameter of 8 inches, and wear them down to 4 or 5 inches. These small stones are highly proper for razors, in order to give to the blade a requisite degree of concavity and corresponding thinness to the edge. The razors are next glazed upon laps of metal, of a size corresponding with the size of the stone, and afterwards polished upon a polisher of wood covered with leather, similar to those used for penknives. The process of polishing, indeed, is always performed on the same kind of tool, differing only in size.

Grinding of Scissors.

The stones made use of by the scissor-grinder are of two kinds; the one of the same size and quality with that used for penknives, and the other of the same nature with that used in the grinding of table-knives, and which the workmen term a whitening stone. The first is employed to grind the inside of the blades, and the latter for grinding the outside. Scissors, the blades of which alone are hardened, are never sent to the grinder before they are hardened and tempered. After the blades of the scissors are ground they are returned to the maker, and are fitted and screwed together, and properly adjusted for cutting. This being done, they are taken to pieces and returned to the grinder. The scissors being slightly ground over again are finished upon their appropriate glazer. The insides of the blades, and all the other parts which are not rounded, are glazed upon a glazer of metal, of a size corresponding to the stone on which they were ground; for the inferior articles the glazer is of wood.

When the shanks of scissors are sufficiently plane to admit of grinding, they are sent to the shank-grinder, a workman solely employed in grinding the shanks and in dressing those parts of the scissors which have been filed, and which cannot be touched by the glazer.

The shanks of larger and commoner sorts of scissors are ground upon a stone similar to that used for grinding the shanks of forks, but the finer kinds are ground upon the Wickersley stone already described. Being ground, they are glazed upon a glazer of wood faced with leather, of the same size and shape with the shank of the scissor. The remaining parts of the scissors, which have been only filed and rubbed with sand but are still destitute of polish, are finished by brushing.

The brush is an instrument consisting of a circular piece of wood set upon the face with very hard bristles. Two brushes are generally employed in succession. The first

is made use of with grease and emery, which gives a coarser sort of polish. The second is used with crocus and water to give the proper finish to the surface. If the blades of the scissors are required to be polished, which is frequently the case, they are again sent to the first grinder, who polishes them upon a polisher similar to those described for razors and penknives. It will be here proper to remark that the shanks of the above kinds of scissors, being soft, cannot assume the polish with crocus, as nothing but cast-steel in the hardened state is susceptible of that peculiar lustre. An imitation of polishing is, however, given to the soft shanks by means of a burnisher of polished hardened steel.

The more delicate and finer sorts of scissors, in order to render all the parts susceptible of polishing, are hardened quite up to the bow, in consequence of which the order of manufacturing is a little varied, from that of the scissors having soft shanks. After being forged, filed, and having the hole drilled for the screw, the insides of the blades are ground, and they are fitted and screwed together. They have next to be hardened and tempered, and as it is a common property of steel to warp during that process, the two sides of the scissors are firmly bound together by means of iron wire. The screw being withdrawn, which would be liable to be hardened along with the scissors, they are heated red-hot all over, and immersed in water up to the bow.

After being thus hardened they are heated, for the purpose of tempering them till the blades appear of a purple and the shanks of a blue colour. The wire is then taken off, and the scissors are finished by processes similar to those above described, with the difference of the shank being polished with crocus along with the blades. After the scissors return the last time from the grinder they only require to be sharpened, wiped clean and screwed together. Previous to wiping, however, they are generally put into pulverized quick-lime, which greatly tends to the preservation of their lustre by absorbing the moisture from the surface; the presence of which is well known to facilitate the rusting of polished steel.

Some of the very fine scissors are elegantly and variously ornamented. Formerly they used to be ornamented with studs of gold or polished steel, arranged round the joint of the scissor or along the shank.

The studs are each furnished with a small tang, by which they are inserted into small holes made in the scissors. The holes are made while the scissors are soft, and the studs are inserted after the scissors are polished.

More recently the same parts are inlaid with circular bits of gold, which are polished along with the scissors and afterwards ornamented on the surface by engraving. Scissors are also ornamented by means of gilding, blueing, and etching. The gilding is performed in two ways; the first by dipping the finished article into a solution of muriate of gold in alcohol; the second with metallic gold laid on by means of heat. The first kind of gilding has been rejected on account of its want of permanency. The second, though very durable, is objectionable on account of the heat employed in the process, which is so great as to make the scissors too soft.

Various devices, such as letters, coats of arms, &c. are sometimes put upon scissors, but more frequently upon razors and swords, by means of etching. The figures are drawn upon the polished surface with a varnish, made by dissolving resin in oil of turpentine. Every other part of the articles is covered with the same varnish, excepting what is to form the ground of the picture. The exposed part is then covered with dilute nitric acid, which is suffered to remain upon it till it is supposed to be sufficiently corroded. It is then rinsed in water to take away the acid, and the varnish is removed by means of oil of turpentine. The ground of the picture appears of a dead white, while the figure, and other parts of the article, display their original polish.

Cutlery made of Pig-Iron.

Great quantities of various kinds of cutlery have been made of pig-iron, by means of casting, particularly forks and scissors. The models are made of lead, alloyed with a little antimony. The articles are cast in sand, in flasks similar to those used in casting small articles of brass. The metal employed is of that sort of pig-metal known by the name of N° 1, from the large quantity of carbon contained in it. It fuses at a lower temperature, and becoming more liquid on that account, it is the only kind which can be used for small articles.

The metal is fused in crucibles of Stourbridge clay, in the common air furnace employed in iron founderies. The articles, when cast, are almost as brittle as glass. This, in a great measure, is occasioned by the moisture in the sand, which effects this change upon the metal in a manner similar to that by which steel becomes hardened. In order to obviate this hardness, the castings are cemented with ashes or sand, for the purpose of annealing them. Cast-iron pots of a cylindrical shape are employed for this purpose. They are about 12 inches diameter, and about the same depth. A number of these pots are filled nearly to the top with the goods to be annealed: a quantity of fine sand or ashes is then employed to fill up the interstices, and to cover them completely, so as to exclude the air. The pots are placed in a furnace, and are surrounded with small coaks, for the sake of carrying on slow combustion. They are heated very gradually to a temperature little short of fusion, and they are as gradually allowed to cool. The whole time occupied in heating and cooling is from 24 to 30 hours. They are found, after this process, to have become very soft, and to be capable of bending a little without breaking. They afterwards are finished in a manner similar to those which are forged, with the exception that they are not hardened and tempered: were they subject to that process, they would return to the same state as before annealing.

Notwithstanding the great demand which has been for cast cutlery, on account of their very low price, they are so completely destitute of utility, that ultimately they cannot fail to disgrace both the merchant and manufacturer. If a preference can be given to any of them, it is in favour of the scissors. The knives and forks are not only liable to break, but they soon turn black, and can be very little improved by the common mode of cleaning, as by the best means they are only susceptible of a miserable polish.

Various attempts have been made with a view to improve the cast cutlery, the most successful of which is by Mr. Lucas of Sheffield; and for his method he some time ago obtained a patent. By Mr. Lucas's process, the cast metal articles are converted from their brittle and crude state into malleable iron or steel at pleasure, without injuring the surface, or distorting the figure of the article. Nails of various kinds have been made in this way, more flexible and equally tenacious with those of wrought iron. This method consists in stratifying the articles, in pots similar to those employed for annealing, with an oxyd of iron. Calcined iron-stone pulverized was first made use of, but was found to make the surface of the metal so rough as to render those articles useless. This inconvenience was in some measure obviated by laying

a thin stratum of sand between the metal and oxyd of iron. Any sort of earth, containing a portion of the oxyd of iron, is capable of bringing about this change. The red sand which abounds in some countries, or loam, or clay, containing oxyd of iron, would answer very well. The theory of this process is obvious. The cast-iron consists of iron and charcoal, or carbon; and it is to the presence of the carbon that we attribute the peculiar qualities of cast-iron different from those of a malleable iron and steel. The oxyd of iron, with which the cast-iron articles are stratified, consists of iron combined with oxygen. During the process of cementation, the oxygen of the oxyd combines with the carbon of the cast iron, forming carbonic acid, which is dissipated in the form of air. For the particulars of the process, see the articles IRON and STEEL.

Specimens of scissors, table knives and forks, and even penknives, have been made so complete by the above process, that the best judges could not distinguish them from those made of the best steel. An insurmountable objection, however, still remains, which will preclude the application of this important discovery in the manufacture of those articles which require a fine edge, and every other article which requires to be hardened and tempered

This metal, previous to hardening and tempering, is equally tough with the best steel or iron, but afterwards becomes very brittle, at least much more so than we should expect from steel so apparently good. The reason of this will be explained under IRON and STEEL.

Handling of Table Knives.

The handles of table knives are made of ivory, bone, horn, and wood. They are formed in two different ways: one, by drilling a hole into the handle, and cementing into it the tang of the knife. This kind is by the manufacturers termed round tangs. The other kind of handle consists of two sides, which, when laid on each side of the tang, and paired together, form the handle. The two sides are termed scales, and knives of this kind are called scale tangs.

Ivory handles are the most valuable, and in the greatest repute. The greatest part of them is made for the round tangs. These are of various patterns, such as octagon, oval, and fluted. The octagon and oval handles are filed into the intended form, and afterwards rubbed first with fine sand and water, and afterwards with powdered chalk and water. The fluting of the handles is performed by means of a sharp tool of the scraping kind, having the figure of the flutes upon its face.

The tangs are cemented into the handles with rosin mixed with whitening.

A very convenient and durable handle is made of stag horn. The round parts of the horn which are of proper thickness are selected for the round tangs. The outsides of the other parts of the horn are cut into scales, which make the scale tanged handles. The surfaces of the stag-horn handles are invariably left in their natural state.

The small end of the ox-horn, termed the tip, is generally employed for making the handles of table knives. The tips are formed into hafts of a great variety of patterns, by means of pressing between two dies. This advantage is obtained from the well known property of horn being so soft and ductile when hot, as to admit of considerable extension. The dies employed for pressing the horn are represented in *fig.* 2. A and B, the upper and lower dies, are made to form the bits of a pair of tangs, on the even faces of which the exact figure of the handles is formed, as represented in the figure.

The pieces of horn intended to be pressed are first softened in hot water, and then cut to the size deemed requisite exactly to fill the mould. The dies are heated to the temperature of about 400° Fahrenheit, or something short of the heat required to burn oil. The horn, with a little oil, is then laid between the dies, which are placed in the pressing vice, *fig.* 3, consisting of a compound lever, acting with a screw at A, and turning round the handle B, similar to the common vice. The force required to be given at the handle is not more than what a man may perform with ease. The motion being now reversed, the tangs are withdrawn, and the horn is found to have received the full impression of the die.

If the handles are plain, and the horn be native black, the first pressing is sufficient; if, however, they are not sufficiently black, they are dyed after the first pressing in a liquid, containing logwood and green vitriol. The process of dyeing takes off that smooth glossy surface given by the dies, which is restored by pressing them a second time in dies a little less than those employed for the first pressing. If the handles require to be fluted, or otherwise ornamented, they are pressed a second time in dies containing the intended figure.

The above handles, after they come from the press, require only to have blades inserted, and to be polished by means of rotten stone or chalk and oil.

The handles of bone are made from the shank of the ox. The thickness of the solid parts of the bone is never sufficient to make the handles equally thick with those of ivory. Some of the bones are very dense and hard, but can always be distinguished from ivory by the colour. Such handles, in order to correct their defect in colour, are dyed green in liquid, consisting of the oxyd of copper dissolved in aqua ammonia. The hartshorn of the shops, being the cheapest preparation of ammonia, is always used. The proport[illegible] are about seven ounces of the oxyd of copper to one gallon of hartshorn.

After dyeing, the blades are cemented into the handles, which are afterwards polished. When the dye does not contain any substance capable of rusting the blade, the handles are dyed after the blades are inserted.

Various kinds of wood are employed in making the handles of table knives. The very common articles have handles of birch wood, which are expeditiously made by being turned in an oval lathe. They are afterwards dyed black or red. After this they only require the blades to be put into them, and to be burnished with a smooth stone, termed blood-stone. A superior kind of wood handles are made of various foreign wood, such as lignum vitæ, ebony, &c. Handles are sometimes made of very thin silver in the sheet, and of plated copper. The thin metallic shells, which form the outside of the handle, are made in two halfs, by being forced into a steel dye, by means of lead; the two sides are afterwards soldered together, and the hollow part filled up with a cement of rosin and pulverized brick. The cement serves to give firmness to the thin shell of metal, and at the same time to secure the blade.

Handling of Penknives.

The handles of penknives in general consist of three parts, *viz.* the outer scales, the inner scales, and the spring. The outer scales, which are only ornamental to the knife, are made of various substances, such as horn, stag-horn, ivory, bone, tortoise-shell, and pearl. The two latter substances are employed for the most valuable knives. The beautiful variegated horn stands the next in estimation. But the most durable scales are made of stag-horn.

The inner scales, which serve to give firmness and dura-

bility to the knife, and to which the outer ſcales are attached, are made of iron, braſs, and ſometimes of ſilver: the ends of the inner ſcales intended to receive the blade is in general made thicker, and is termed the bolſter of the knife. The ſcales of thoſe knives having no bolſters are cut out of thin plates of the metal of which they are made. Iron ſcales with bolſters are forged with the hammer.

The ſpring is of ſteel, running along the back (and in ſingle blade knives round the end) of the handle, and ſerves to ſeparate the ſcales from each other; and by its elaſticity exerted upon the tang of the blade, it ſecures the knife in the ſituations of being ſhut or open. The inner ſcales and the ſpring being forged, and the outer ſcales being provided, they are put into the hand of a workman, who finiſhes the whole of the handling department.

His tools conſiſt of a vice, a ſmall anvil, and hammer, a variety of files, ſteel burniſhers, a breaſt-plate, drill-bow, and drills of various kinds; a glazer coated on the face with emery and glue, to poliſh the different parts; and a buff, which is an inſtrument ſimilar to a glazer; but inſtead of being coated with emery and glue, it is uſed with oil, and fine ſand, and rotten-ſtone. It is employed to poliſh the ſurface of the outer ſcales. The buff and the glazer are turned by the foot, in a manner ſimilar to that of the common ſtreet-grinder. He is alſo provided with a number of hardened ſteel plates, about one-twelfth of an inch thick, and in ſhape correſponding to the different patterns of the handles: each plate contains holes in ſituations anſwering to the holes in the handle, by which the ſpring and blade are ſecured in their places. The inner ſcales are each ſecured to one of the plates above, for the ſake of drilling holes through them oppoſite to the holes in the plate. The ſcales are then faſtened on each ſide of the plate by temporary pins, and the edges are filed down to the plate. By this means the handles are made exactly of the pattern required. The ſpring is next drilled, placed between the ſcales, and ſecured in its proper ſituation by temporary pins, till it is filed quite level with the edges of the ſcales. A hole being drilled through the tang of the blade, one of the above pins is taken out, and the ſpring thrown back, ſo as to allow the blade to paſs between the bolſters, in which ſituation it is faſtened by means of a temporary pin. The tang is then filed ſquare, to correſpond with the bolſter and the ſpring.

The blade, the ſpring and the ſcale being properly adjuſted to each other, the different parts are ſeparated by taking out the pins.

All the viſible parts of the ſpring are next filed ſmooth, and the ſpring bent a little inwards, for the ſake of giving it greater power when placed in its intended ſituation. The ſpring is then hardened, by heating it red-hot and immerſing it in water; it is afterwards tempered, by rubbing it over with greaſe, and heating it till the greaſe inflames: the viſible parts being glazed and burniſhed, the ſpring is deemed finiſhed.

Our next proceſs is to place the outer ſcales of horn or other ſubſtance upon the inner ſcales.

Scales of horn or tortoiſe-ſhell are heated, and expoſed while warm to the action of a ſcrew-preſs, for the purpoſe of making them flat.

The ſcales are then made of uniform thickneſs, by means of filing. In the next place, the ſhield of tin or ſilver is introduced.

As this is a proceſs of ſome ingenuity, at leaſt ſo far as concerns the forming a receſs for the different ſhaped ſhields, we ſhall deſcribe the tools employed, with the aſſiſtance of the following figures.

Fig. 2. is a plate of hardened ſteel, about one-twelfth of an inch thick, and of breadth and length ſuitable to the ſize of the ſhield. A hole is made through the plate exactly of the figure of the ſhield; and every different pattern of courſe requires a different plate. *Fig.* 3. repreſents the drill employed to cut the intended figure in the horn or other ſubſtance.

This differs from the common drill, in having the ſprings faſtened into the part B. by means of two ſcrews, A, A. The ends, *b*, *b*, are made ſharp like the points of a drill, and are capable of boring up to the ſhoulder *a a*. The plate, *fig.* 2, is placed upon the ſcale, and fixed in the vice; the ſprings of the drill are then preſſed till the ends, *b*, *b*, enter the hole of the plate. It is plain that if the drill be preſſed and turned round, that the force of the ſpring will cauſe the cutting parts to make a figure the ſame as that of the plate. The depth of the receſs is limited by the ſhoulders, *a*, *a*. The ſilver ſhields are cut out of the ſheet by means of a punch; thoſe of tin are firſt caſt, and afterwards ſtruck into a receſs made in a die by means of the plate and drill above mentioned.

The ſhield being ſecured in its proper place, the outer ſcales are pinned upon the inner ones; the compound ſcales are next pinned together with the temporary pins, and both their edges are filed and finiſhed together. They are again ſeparated, and the inſides of the inner ſcales poliſhed; after which the blades, ſpring, and ſcales are all riveted together. The next thing is to file and burniſh the joint and bolſter; and laſtly, to finiſh the outer ſcales. This is performed by filing, ſcraping, and buffing, firſt with fine ſand, and laſtly with rotten-ſtone.

Handling of Razors.

After the blades of razors are ground and poliſhed, they only require to be handled and ſet or ſharpened.

The handle of a razor conſiſts of two ſides, called ſcales, which are made of various ſubſtances. The moſt valuable are made of pearl, tortoiſe-ſhell, ivory, and native horn. The handles of the greateſt quantity of razors, however, are made of preſſed horn, ſome of which are dyed black, and others ſpotted to imitate tortoiſe-ſhell, and hence are termed mottled ſhell. Pearl is a ſubſtance very ſeldom made uſe of for the handles of razors. In the firſt place, they are very expenſive, on account of the very high price of the ſhells; and ſecondly, they are very liable to be broken, as well in manufacturing as when in uſe. Ivory makes a very neat handle; but their very great expence in manufacturing, added to the great price of the raw material, renders their price very high. In the opinion of moſt, they are not neater, nor by any means ſo durable, as the handles of preſſed horn. Tortoiſe-ſhell makes a beautiful handle, when uſed in the ſtate in which it is cut from the ſhell; but on account of its high price, it is uſed with more economy by preſſing it in a manner ſimilar to that of horn. The preſſing, however, deprives it of a great part of its beauty. No handles for elegance and durability can exceed thoſe of native horn, when the ſpecimens are properly ſelected for the purpoſe. Since, however, the handles of preſſed horn are in no way objectionable, but, on the contrary, are the moſt generally preferred, we ſhall be more particular in the deſcription of this branch of manufacture.

Having already deſcribed the proceſs of preſſing the handles of table knives, and ſince the ſcales of razors are preſſed by a method ſtrictly ſimilar, it will be unneceſſary to give a ſeparate deſcription.

The dies in which the ſcales of razors are preſſed are made to preſs one pair at a time. The pieces of horn in-

tended for preffing are in the procefs fometimes extended as much as two inches.

The handles of preffed horn are divided into three varieties, *viz.* the native black, confifting of horn which is black previous to being preffed; thofe of the fecond variety are fuch as are dyed black, or other colour, after being preffed; and handles of the third kind are thofe deftined for mock fhell, for which the moft clear and colourlefs fcales are felected.

Thofe of the firft kind, after preffing, retain their native black, and are much efteemed for their permanent colour. The fcales, which are partially coloured, are generally dyed black with a dye made of logwood and fulphat of iron: fome are dyed red, and others green. The former are dyed with archill, and the latter with indigo diffolved in the fulphuric acid.

The imitation of tortoife-fhell is performed by a procefs called fpotting, which confifts in the application of a compofition to the furface of the horn, by which it becomes irregularly coloured.

The compound confifts of one part of minium, four parts of common pot-afh, and ten parts of quick-lime: as much water is added as will give it a pulpy confiftence. It is then laid upon the upper furface of the fcale with a flick as carelefsly as poffible, and is fpread thicker in fome parts than in others, for the purpofe of giving a variety of fhades. The fubftance is allowed to remain upon the furface for fix or eight hours; and the latter part of the time they are placed before the fire. After the compofition is removed, the furface exhibits a ftriking imitation of tortoife fhell. The fingular effect of this fubftance is evidently the refult of fome chemical change. The lime appears to anfwer two purpofes: it takes the carbonic acid from the pot-afh, and at the fame time ferves to give a proper confiftence to the mafs. The lead and the pure pot-afh together are effential to producing the effect; though, when feparately applied, no change is obferved. The fact is, that the colour is produced by the diffolved oxyd of lead in the alkali. A colourlefs folution of this kind may be advantageoufly ufed for the fpotting of horn. May not this compound be found of ufe in giving colour to other animal fubftances, fuch as hair, leather, &c.?

The handles of razors are frequently ornamented by means of fhields of various figures, fome of which are of filver, others of yellow metal, and of an alloy formed of lead and tin. The filver and yellow metal fhields are preffed into the fubftance of the horn by means of a prefs fimilar to a fly-prefs. The fcale and the fhield are placed between the two dies of a figure correfponding with the fhape of the fcales, the dies being previoufly heated to a temperature fomething fhort of that employed in the firft preffing. A fufficient force is then exerted upon the fcrew to force the metal into the horn. Figures, letters, and other ornaments, are introduced by the fame method.

The fhields of lead and tin are put in by firft making in the fcales a proper recefs, by means of the fpring-drill defcribed in *figs.* 2. and 3., and afterwards filling it with the melted metal. The greateft number of fhields are of this kind.

The handles of pearl, ivory, &c. which cannot be made by preffing, have the proper fhape given to them by means of the file. The fhields are then introduced by firft making the proper recefs with the fpring-drill, and afterwards fecuring the fhield by means of rivetting, but more completely by the following method. After the fhield is cut out to its proper fhape, it is made concave on one fide, and convex on the other; at the fame time the edge is a little bevelled towards the convex furface. The cutting part of the fpring muft be fo formed as to make the bottom of the recefs to receive the fhield a little larger than at the top. The fhield being then introduced with the concave fide downwards, and hammered upon the convex fide, becomes firmly fecured.

The fcales of the handle in the ftate already defcribed are now fit for the reception of the blade. A piece of white metal, an alloy of lead and tin, called the head, is next placed between the fcales at one end, to allow the blade to go between when the razor is fhut; the blade is then fcrewed in its place, and the fcales faftened together by means of rivets, which are of iron, brafs, and fometimes of filver. Zinc wire has been recently ufed for the purpofe, and receives a good polifh. The handles of razors in the ftate left by the prefs and the file are firft fcowered with fand and water, and afterwards polifhed upon a buff.

A fuperior kind of fine cutlery is manufactured in London, chiefly by the furgical inftrument-makers: the excellence of which confifts in the great attention paid to its fabrication; the quality of the fteel, and above all to the correctnefs of the feveral temperatures under which it is hardened, and the reduction of this by the procefs called tempering.

The eftimation thefe articles are held in, allows the manufacturer to employ the fuperior workmen, and alfo to reject, during any part of the procefs of manufacture, fuch articles as from flight flaws, cracks, or even any inferior quality in the fteel, may be objectionable.

The procefs of the manufacture differs alfo from the circumftance of the fame workman beginning and completing the article. Engines and complicated machinery are never ufed: therefore his fkill and abilities being exerted, greater perfection is obtained. The hardening of fteel depending on the quick abftraction of the heat given, different mediums are made ufe of, as quickfilver, water, oil, &c. The tempering, or reduction of the hardening, is not governed by the colour only, but by a more accurate method (propofed by Hartley); the exact variations of temper are given in a fluid, into which a Fahrenheit's thermometer graduated to the boiling point of mercury is immerfed, and the delicacy of this operation may be fufficiently underftood, from the various colours produced on the fteel, at the various temperatures fhewn by the thermometer. The change or fcale takes place at 430, and finifhes at nearly 600. Nine changes of colour are obfervable at about 20 degrees diftance of each other, *viz.*

430 Slight colour inclining to yellow.
450 Straw colour, pale.
470 Yellow.
490 Brown.
510 Brown with purple fpots.
530 Purple.
550 Bright blue.
560 Blue.
600 Blackifh blue inclined to fcale or oxyd.

From 430 to 470 is chiefly employed for razors, and fome of the finer edged furgical inftruments.

470 and 490 for penknives, and fome pointed inftruments.

From 510 to 550 includes pocket-knives, table-knives, carvers, fciffors, &c. &c.

The experience of the workman is much required, and alfo a knowledge for what purpofe the edge is to be employed, during thefe three ranges of temperature.

550 and 560 Spring temper.

Setting.

The operation of ſetting an edged inſtrument, is the giving it a more permanent, or laſting edge, by means of a hone, or any other fine cutting ſtone. Every article is left from the wheel with a thin wiry or notched edge. This muſt be removed, and one ſubſtituted of an angular form; the more obtuſe the angle, the ſtronger the edge, and *vice verſa*. This angular edge is obtained in ſeveral ways; ſometimes by the thickneſs of the back of the inſtrument, but more generally by the elevation of the back from the ſtone.

Razors are ſet upon a ſtone brought from Germany. Their backs being thick, they are laid perfectly flat, and rubbed backward and forward on each of their ſides, till the wire or notched edge gives place to a fine ſmooth one. The uſe of a ſmall quantity of oil on the ſurface of the ſtone is requiſite.

Penknives are ſet upon a ſtone brought from Turkey, and from its property of abſorbing oil, it is called an oil-ſtone. They are held at an elevation of the back juſt ſufficient to keep it from touching the ſtone; and the greateſt attention is here requiſite, to give them the ſame exact elevation, during the removal of the wire edge. They have alſo a few ſtrokes given them as a finiſh, upon a hard kind of green ſtone.

Sciſſors are ſet upon the oil-ſtone; they are held nearly upright, that their edges may be turned toward their inner ſide.

Pocket-knives, carving, and table-knives, are ſet at an elevation, upon a ſtone, called a rag-ſtone, of a fine ſandy texture, and without the uſe of oil.

Fig.1. Two Troughs of a Grinding Mill.

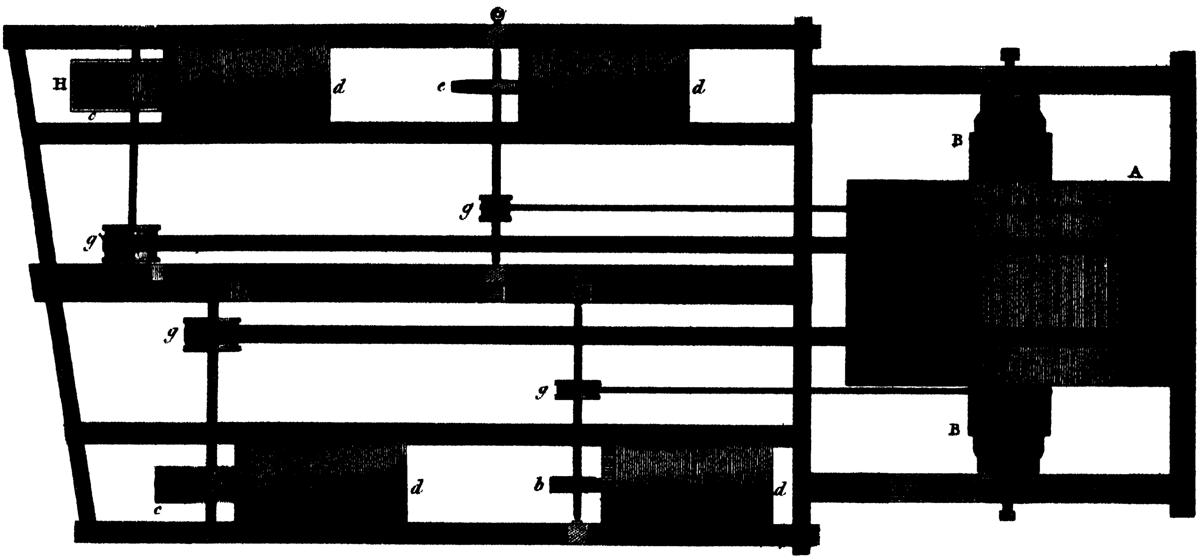


Fig.3. Pressing Vice

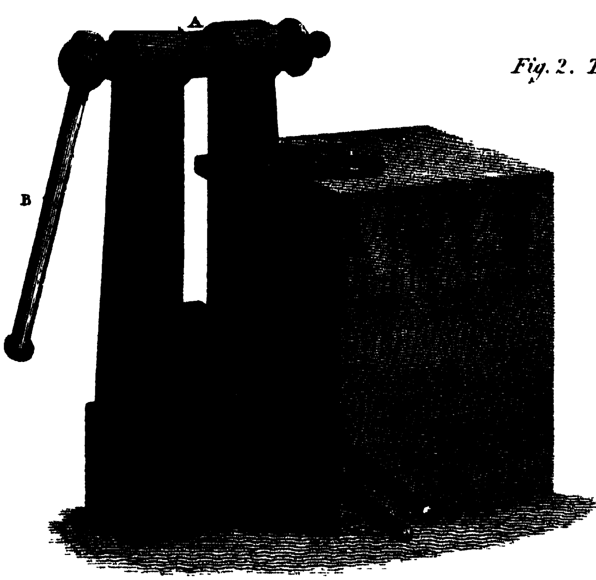


Fig.2. Tongs for pressing Knife Handles.

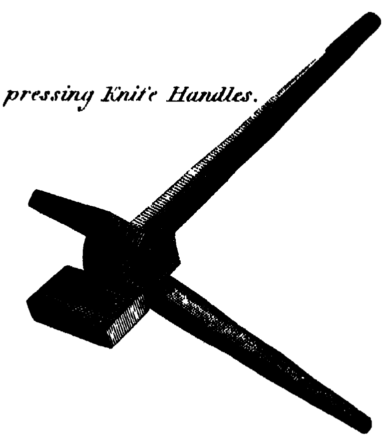


*Fig.2**

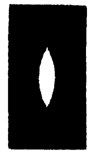
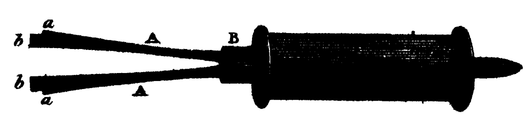


Fig.3. Spring Drill.



Engraved by Wilson Lowry.

Published as the Act directs 1810, by Longman, Hurst, Rees, Orme & Brown, Paternoster Row.

Cutting-engine

Cutting-*Engine*, in *Mechanics*, is the name of an engine, which divides and cuts a wheel, pinion, or rack, into any affigned number of teeth, which office it performs both with accuracy and expedition. While the art of conftructing wheel-work was yet in its rude ftate, the dividing of a wheel into the requifite number of circular parts, and cutting away the notches or fpaces by a manual operation with a file, was not only a tedious but an imperfect way of proceeding, which left fuch inequalities in the fize and fhape of the tooth, as were but ill fuited to tranfmit any applied force in an equable manner, or to perpetuate the duration of the parts once made. To facilitate fuch manual operation by a file, the fimple platform was invented, defcribed by father Alexander, in his book on clock-making, which was a circular plate of brafs, from ten inches to a foot, or more, in diameter, with as many concentric circles thereon, as the ufual numbers of teeth in the wheels and pinions of clock-work required to be divided into correfponding parts of a circle. In the centre of this platform was fixed a ftem, or faft arbor, round which an alidade, ruler, or index, with a ftraight edge, pointing to the centre, turned freely into

any given point of a required circle, by means of which the divisions of any given circle were transferred to a wheel, placed on the said stem under the said index, by a marking point. This mode of dividing a wheel is still imitated by the enamellers and engravers of clock-faces, and is certainly an easy way of transferring divisions from a larger to a smaller circle for various purposes, where the accuracy of an astronomical instrument is not required; but still the spaces were required to be cut by hand with a file; at length a little frame was mounted on the index, which was contrived to direct and confine the file in such a way as to cut the notches of a wheel, placed over the index, with less deviation from the truth than could be managed by mere manual dexterity; this addition, no doubt, led to the adoption of a circular file, or cutter, and of such other appendages as completed the construction of a simple cutting-engine; and it is asserted ["Etrennes Chronometriques" par M. le Roy] that Dr. Hook was the first person who contrived such an arrangement, as could merit the name of a cutting-engine, [machine a fendre.] The doctor's invention, which, like many other of his inventions, has proved to be of permanent and great utility in mechanics, consisted of an entire transmutation of the old stationary platform, with its moveable appendages, into a moveable platform inserted into a strong metallic frame with stationary and additional appendages; the machine thus converted into an engine, or self-acting piece of mechanism, consisted of the strong frame; the sliding supporting bars of the platform, or plate, with an horizontal screw of adjustment for distance from the circular file; the divided plate with a revolving arbor to receive the wheel to be cut; and the alidade fixed to the great frame, in the position of a tangent line to any of the divided circles, and applying its bent and rounded point to the punched marks of division on the circle successively, as the plate revolved, in the act of cutting the successive teeth of a wheel. This construction of the engine is very nearly the same that remains in the tool shops of the present day. The original divisions of the circles, *viz.* 360, 300, 150, 90, 60, &c. are also retained in the ordinary engines, though many of the smaller numbers are included in the larger ones, and are therefore superfluous; for taking every fourth hole of 360, is the same as using the circle of 90, or every sixth the same as using the circle of 60; also taking every other hole of 300 is the same as using the circle of 150. As these ordinary engines are very limited in their operations, by reason of their powers extending only to the numbers marked on the divided circles; and as the prime numbers are not usually inserted, we find that different ingenious men, both in France and England, have contrived additional apparatus to render the engine more perfect. Indeed so long ago as the year 1716, Henry Sully brought into England, among his collection of new tools, a superb engine, made by M. de la Faudrière, which has been mentioned by Julien le Roy, and described by Thiout in his "Traité d'Horlogerie." About 1730, M. Taillemard made further improvements in the cutting-engine, particularly by introducing a tubed arbor instead of an arbor with a square hole, which had been usual before. After Taillemard, his apprentice Hulot continued to construct engines in a superior way in France, and is succeeded by his son Hulot the younger, whose execution is deemed equal to that of his father.

M. Fardoil, another French mechanist, contrived a plate to his engine, which afforded the means of cutting any number of teeth in a wheel, prime or composite, by a circular rack and endless screw, the latter of which is fixed in a stationary position. The description of this engine is given in Thiout's work which we have already mentioned, to which the curious reader is referred for a full account. The number of notches on the circumference of the plate, which has no divided circles, is stated to have been 420, so that one revolution of the screw answered to a tooth, where the wheel was required to be cut into 420 teeth, and in proportion as the micrometer-head of the screw was turned more or less than an entire revolution, were the teeth reciprocally fewer or more numerous than 420. This number seems to have been chosen in preference to any other, by reason of the many composite parts it is capable of being divided and subdivided into. In practice it was necessary to divide the number 420, and also the number of teeth of the proposed wheel by some common divisor, in order to reduce the terms into their lowest denomination; then the quotient arising from the number of the wheel's teeth, in using the common divisor, was made the number for the divisions of the micrometer-head, and the larger quotient coming from the term 420, was the proper number of divisions of the said divided micrometer-head necessary to pass the index after cutting each tooth. An example will render this mode, which was certainly ingenious, intelligible to any ordinary reader, who has seen an engine. Let the number of teeth to be cut be 249, then the common divisor will be 3, and $\frac{420}{3} = 140$, likewise $\frac{249}{3} = 83$; the smaller quotient therefore 83 is the number of divisions proper for the micrometer-head, fixed to the axis of the endless screw, and 140 of those divisions must pass the index after each cutting operation; the result in this case will be the same as if the micrometer had had 249 divisions, and 420 of these had passed the index after the cutting of each tooth. The micrometer-head had a ratchet wheel and contrivance for making number *one* of the divisions come back to its original situation after each operation, like the contrivance in the engine for dividing sextants and nautical circles, which engine will be seen in another place. This mode of cutting all kinds of numbers, ingenious as it is, requires, however, various micrometer-heads to suit such prime number, which prime numbers themselves require dividing previously; consequently the real advantages of this contrivance are by no means adequate to its professions. Berthoud has given a description and drawing of a French machine for cutting the teeth of wheels and pinions, in his "Essai sur l'Horlogerie," and also in his "Histoire de la Mesure du Temps," such as he considers of the best construction; and in his "Traité des Horloges Marines," he has described an apparatus for forming the ends of the teeth by means of a concave file confined in a frame, which makes it move in a given direction; which description, together with the drawing, is copied into his "Histoire de la Mesure du Temps." We satisfy ourselves with a reference to these contrivances, in order to describe two engines of English construction, which have not been previously described, and which, we think, merit a particular notice, both as specimens of ingenuity, and as engines of great utility in daily practice. These engines we have already referred to under our article CLOCK-*making*; one as being used by the late Brown of King-street, Seven-Dials, London, which we learn was projected, and partly made between the years 1770 and 1780, by Hindley of York, when in London; and the other, as being contrived by the late Rehé, mechanist to the naval board of works, and purchased by Troughton for the use of a relative, who is since dead, and who is succeeded by James Fayrer of No. 35, White Lion-street, Pentonville, who now uses it. On a reference to Mr. Troughton's books, we find, that his late brother divided Rehé's engine-plate in

the year 1783, which fixed the date of its conſtruction; and from this as a model it was, that the inventor conſtructed a ſimilar one for Dr. Milner, the dean of Carliſle, of the expence of which that gentleman had not formed a competent judgment at the time he gave his order, to make as good an engine as could be conſtructed, which occaſioned ſome demur about the payment. The worthy dean little ſuſpected that the engine he had ordered would coſt him three hundred pounds or guineas; and the reader will not be leſs ſurpriſed to be told, that Rehé's engine, with its apparatus, was ſold at his ſale for 700l.

Cutting-Engine by Hindley.

The cutting-engine contrived by Hindley is repreſented in *Plate* II. of *Engines*. *Fig.* 1, is a perſpective view of the entire engine in a ſtate proper for cutting, with the exception of the foot-wheel ſurrounded by the cord that gives motion to the revolving cutter, and of the bench to which that wheel is attached, and on which the engine reſts; but the reader who has ſeen a common turning-frame, or other mechaniſm turned by the foot, can readily conceive how a ſimilar motion may be given to the cutting-engine by a lever, placed nearly horizontally under foot, and connected with the crank of the large wheel's arbor: *figs.* 2 and 3, ſhew the cutter frame detached from the engine, the firſt of which ſuppoſes the eye placed over it, and the other at one end when viewing it; we ſhall ſpeak of them more minutely, and alſo of ſome figures in *Plate* III., when we have deſcribed the engine in its entire ſtate.

A B C D E F is a ſtrong iron frame, fixed by the end pieces at E and F to a ſteady bench, to which alſo the large wheel for the cord is faſt, but not ſeen in the drawing; the ſide-pieces of the frame, A B and C D, are exactly parallel to each other, and their upper edges are terminated by two ſlopes that form an oblong and obtuſe wedge, on which the ſunk baſe of the cutter-frame, G H I K, reſts, and ſlides ſmoothly when one of the handles and micrometer head at L turns the horizontal ſcrew, between B and D, that is tapped into a piece of metal behind the cutter-frame and attached thereto. M is a ſtrong tube of braſs fixed to the ſide of A B by four ſcrews ſeen to the right and left in the ſquare part to which the tube is faſt: within this fixed tube M there is another tube N ſeen above it, which conſtitutes the revolving arbor of the large circular plate O, under the frame; the annular ſhoulder-piece, P, reſting on the top of tube M, and pinned or ſcrewed faſt to the interior tube N, bears the whole weight of the plate O: a ſection of theſe tubes, containing another tube and arbor of a pinion to be cut, is given in *fig.* 1. of *Plate* II. The plate, O, is about a foot in diameter, and marked into a number of divided circles, with holes drilled through at each divided point, the uſe of which will be explained preſently. Through the inner tube N, or axis of the plate O, paſſes a ſolid arbor on which the plate, Q, is fixed, with a few notches cut on one ſide; this ſolid arbor is fixed by a ſcrew, under the centre of the plate O, as ſeen in *fig.* 1. *Plate* II., and may be taken out at pleaſure, and a projecting pin fixed in this ſolid arbor, below the wheel, takes into a correſponding notch made in the tube N, which contrivance makes the ſolid arbor and tube, N, reſt or revolve together, as circumſtances require, and alſo along with them the circular piece of metal Q, placed faſt to the ſolid arbor by a collet and tapped nut ſcrewing down upon the ſuperior end of the arbor, formed into a ſcrew, as ſeen in the figure. Of theſe ſolid arbors there is a variety belonging to the engine, with their ſuperior ends varying in thickneſs to ſuit the different holes of different plates Q, or in other words, to ſuit the central holes of different wheels previouſly turned and fitted to their reſpective arbors; but it is not neceſſary to introduce thoſe different arbors into our drawing, as their ſhape is common, and their dimenſions vary only at the ſuperior end, where the wheel fits. In conſequence of the connection of the ſolid innermoſt arbor with the tube N attached to the platform or divided plate O, whenever this plate revolves a given quantity, or diviſion of one of its circles, the wheel fixed to the ſolid arbor, above the frame, moves with it preciſely the ſame portion of a circle, and preſents itſelf to the cutter or revolving circular ſaw R, borne by the moveable frame G H I K, and having a ſmall pulley round the poſterior end of its arbor, which is ſeen embraced by the cord that puts it in motion. Whenever the handle S, attached to the cutter-frame, as may be ſeen more clearly in *fig.* 2, is lowered by hand, the cutter, R, deſcends with it till meeting with the edge of the plate, or wheel Q, it cuts a notch through it, while the moving pulley gives motion to the ſaid cutter; as ſoon as this notch is cut, the depth of which is regulated by the ſcrew of the handle L, that moves the whole cutter-frame, the handle, S, is permitted to aſcend, which it does by means of a ſpiral ſpring ſeen in the middle of the cutter-frame preſſing under the top portion in *fig.* 2; the cutter is then free from the notch of Q, and the latter is at liberty to advance round whenever the plate, O, is moved; during this time an index, with a fixing point, T, called by the French an alidade, holds the plate in a firm poſition, in conſequence of the point, T, penetrating one of the drilled holes of the divided circle, made choice of for the operation; this point, T, is next raiſed by the right thumb preſſing on its oppoſite end at U, while the fingers of the ſame hand turn the plate, the ſpace of one diviſion or more as may be required; the left hand in the mean time graſping the handle S, and the foot continuing to turn the large wheel, that is the firſt mover; the motion of the large plate has now brought Q, the wheel to be cut, a correſponding ſpace round, to the ſituation required for cutting another notch, which the cutter immediately does on being brought down by S, the handle for the left hand, into contact; the operation of raiſing the fixing point T, and of moving the large plate O, another diviſion, is repeated, and the wheel, Q, is again in a ſituation to have its third notch cut; and thus the operations of moving the large plate and lowering the revolving cutter are alternately repeated till there are as many notches cut in the edge of the wheel, as the divided circle contains drilled holes of diviſion, provided the plate is turned only the ſpace of a ſingle diviſion; but when the plate is moved two diviſions of the circle every time the point, T, is raiſed, then the number of notches cut in the wheel will be only half the number of ſuch diviſions; ſo that any divided circle on the plate will ſerve for a wheel that is either the whole number, or any exact aliquot part of that number. For the ordinary engine this deſcription would have been ſufficient to have conveyed to the reader an adequate idea of the operation of cutting a wheel fit for all common purpoſes; but the engine before us is comprehenſive in its uſes, and takes in all numbers prime and compoſite, whether divided on the plate or not, which lie under 360, its greateſt number of diviſions in one circle; nay, it will go even beyond this number if found neceſſary, as will appear from a little cloſer inſpection. In an ordinary engine, the fixing-index, or alidade, is made elaſtic, and placed on the ſide of the principal frame, and is moveable on the end oppoſite to the fixing point, ſo as to be capable of being placed as a tangent line to any one of the divided circles, but has no ſcrew or micrometer to alter its length or poſition when once fixed, on which account a wheel cannot be cut into any other number of teeth, but

ſuch as are laid down on the plate, or ſuch as are derived from thoſe, by taking every ſecond, third, or fourth, &c. hole of the diviſions; whereas in the engine before us the fixing index, U T, is not attached to the frame, but to the four-armed piece of braſs V W X Y, that is moveable round the inferior end of the fixed tube M at V, and connected with a worm-ſcrew by means of teeth cut on its branch Y, as ſhewn in the figure; the worm near Y is fixed by a cock to the end-piece E of the large frame, and has a micrometer head, Z, divided into ſixty notches, inſtead of dividing lines, that the elaſtic index *f*, above Z, ſeen ſcrewed to the ſaid end-piece of the frame, may make ſuch a noiſe in paſſing the ſaid notches of the micrometer-head as are audible to the workman, who therefore has no need to examine the dividing marks by the eye in the act of cutting. The branch, X, has an oblong hole in it, that the contiguous end of branch Y may be adjuſted in it, by fixing the racked end near Y in a proper ſituation to act freely with the worm ſcrew when wanted; the piece of braſs *a*, with a long open in the middle, and ſcrewed at *g* to the ſide, A B, of the principal frame, has the ſcrew, *d*, paſſing through it to fix the branch X, whenever the worm-ſcrew is not required to be in uſe, which in this caſe fixes the index, T U, to the frame A B, but when the worm is uſed, as hereafter deſcribed, the thumb-ſcrew, *d*, is turned back. The arm W *b*, to which the index and fixing point, T, are attached, ſlides, in the adjuſtment for a given circle to be uſed on the plate O, along an under bar of ſimilar dimenſions, which it covers, and which is a part of V continued; the interior end of W *b* is kept to its direction by the fixed clamp, *b*, that moves on pivots near the letter *b*, at one ſide, and has a fixing point that penetrates the holes of diviſion made and numbered, along the upper or ſliding bar, with figures that indicate the diviſions of any given circle to which the fixing point, T, of the fixing index is at any time placed; therefore, when a wheel is required to be cut into any number of teeth, found upon the divided bar W *b*, this bar is ſlided in or out, while the fixing point of clamp *b* is held up, till the hole deſignated by the required number falls under the ſaid point, in which ſituation it is made faſt by the thumb-ſcrew *e*, and the point, T, then falls into one of the drilled holes of the proper circle of plate O, which in ordinary engines contains the numbers itſelf. The index, T U, of the fixing point of the plate O, turns on pivots above *b* when preſſed by the thumb at U, and has a ſpring underneath that makes it return, and holds it faſt in any aſſigned hole of a given circle of the plate during the cutting of a ſpace in the wheel required to be cut; but when the plate is wanted to be at liberty to move a large portion of a revolution for any purpoſe, the ſpring juſt mentioned can be locked, ſo as to hold the point, T, above the plane of the plate, till the act of cutting commences. By the help of this appendage to the engine a wheel may be cut into a number of teeth not divided on the plate in the following manner; ſuppoſe a wheel of 62 teeth were required to be cut, and that there were no divided circle on the plate nearer than one divided into 60 holes, to cut it from; then having fixed the wheel on the ſolid arbor by the fixing nut, in the ſituation of Q, and having ſlided the divided bar W *b* till the fixing point of *b* falls into the hole deſignated by 60 on the ſaid bar, let it be fixed there by the thumb-ſcrew *e*, and let the point T fall into any one of the holes drilled in the circle 60, which will now be exactly under it; alſo let the thumb-ſcrew *d* be turned back to ſet the four-armed piece at liberty to move by the worm-ſcrew Y attached to the micrometer-head Z; in this ſituation of the apparatus cut a notch in the wheel, then preſs on the end U of the index and carry the plate in the direction from O towards T, the quantity of two diviſions, which will be two teeth in the wheel if they were cut, the cutter in the mean time being raiſed from the wheel, as in the drawing: turn in the next place the micrometer ſcrew, and count the turns and parts of the micrometer until the wheel is brought back to its original ſituation; that is, till the cutter on trial is found to drop eaſily into the notch before cut without rubbing on one edge of the notch more than on the other. Let the turns of the micrometer thus counted be 7, and 14 notches or marks out of 60 over, for the meaſure of two teeth in caſe 60 teeth had been the number to be cut, which will be 434 notches on the micrometer-head paſſed over by the index *f*; then if theſe notches be divided by 62, the teeth to be cut there will be $\frac{434}{62} = 7$, for the number of notches that the large plate O ought to be turned back after each tooth is cut, in a direction oppoſite to that of the plate's motion, when made to revolve after the fixing point, T, is raiſed; the proceſs therefore now to be uſed in cutting, is to raiſe the point T in the firſt place, then to move the plate from O towards T, one diviſion or $\frac{1}{60}$ of the circle, after that to turn the micrometer back 7 notches of the 60, which carries the plate back again from T towards O, a ſmall quantity, ſo as to form a tooth of $\frac{1}{62}$ inſtead of $\frac{1}{60}$ of the whole number to be cut. Laſtly, let the notch be cut, and repeat the ſame proceſs at every cutting, and it will be found at laſt that a wheel of 62 teeth has been cut inſtead of one of 60, on account of there being 62 times 7 notches in the 434, that have in the whole paſſed the index *f*, during the time that the wheel has been under the act of cutting. Should it happen, as will generally indeed be the caſe, that there is a remainder in the diviſion of the notches by the teeth of the wheel to be cut, the remaining numbers may be intercalated thus: as a ſecond example, let the number of teeth be 61 to be cut from the ſame circle of 60, and let the turns of the micrometer, as before, be 3, with 37 notches over, out of 60, for the ſpace of a ſingle diviſion on the plate O; in this caſe there will be only 217 or half the former number of notches in the whole, to be divided by 61, the quotient ariſing from which is three, with a remainder of $\frac{34}{61}$, ſo that, properly ſpeaking, $3\frac{34}{61}$ notches of the micrometer ought to be drawn back after every ſhifting of the fixing point T, but this is not practicable without a ratchet, and returning back to the micrometer, which the engine has not got; therefore as 34 is only 3 more than half of 61, and as one notch on the micrometer does not affect the motion of the plate O in a ſenſible manner, the notches may be taken alternately 3 and 4 in ſucceſſion, except in three equidiſtant points of the wheel, where 4 may be taken twice in ſucceſſion, which mode of interpolation of the notches belonging to the remainder, as they accumulate, may be practiſed with any other numbers, and the difference thus occaſioned among the teeth will not be ſenſible even under a magnifying glaſs. The writer of the preſent article has ſeen and examined a wheel of 126 teeth cut from a circle of only 100 diviſions in this manner, which appeared as evenly divided, as if it had been cut from a circle drilled or punched into 126 diviſions.

If the number of teeth to be cut had been taken fewer than the diviſions in the circle uſed on the plate, the micrometer-head muſt, in that caſe, have been turned the contrary way, to augment the divided ſpaces of the plate, and to enlarge the ſize of the teeth in proportion as their number is decreaſed, which effect can now be readily apprehended without further detail.

But this property of being capable of cutting wheels into all aſſigned practical numbers of teeth, is not the only advantage that this engine poſſeſſes over the common engines ſeen in the tool-ſhops: when the cutters of theſe engines

require to be changed, the arbor, on the middle of which they are fixed, requires to be taken out of its frame, and to be replaced and adjusted to the centre of the plate, or middle of the solid arbor, as frequently, which is troublesome: also as the cutter-arbor revolves round stationary pivot-holes, the bottom of each notch cut in a wheel is necessarily a portion of the circumference of a circle, which in a thick wheel requires to be filed into a straight line after the cutting is finished. Both these inconveniencies are obviated in our present engine. To avoid the first inconvenience, the cutter, R, is put on the projecting end of its arbor, and can be taken off and put on without displacing the arbor from its moveable frame. When, however, the cutters vary in thickness, they require an adjustment of their middle part to the middle of the solid arbor that bears the wheel to be cut, which is done by a contrivance seen best in *fig.* 2; where R, as before, is the cutter, and H I an arbor, round the pivots of which the top of the frame, to which the handle, S, is attached, revolves, and to which the said top is united by a small handle *i*; when the screws, *k* and *l*, are loose, the top of the frame, *k l m n*, is at liberty to have a motion in the direction from H to I, or the contrary; but the small handle, *i*, is screwed at the middle to the arbor H I, and at the interior end to the top of the frame, near the fork of the large handle S; so that, as the bearing parts H and I, beyond the two ends of the arbor, have no lateral motion, whenever the screws, *k* and *l*, are loose, and the end, *i*, of the small handle is moved towards H, the whole top, *k l m n*, and cutter, R, are carried towards I, and the contrary when the end, *i*, of the small handle is moved towards I; this side motion of the cutter, and of its arbor, affords the ready means of adjustment for cutting the spaces, and consequently of forming the teeth of any wheel with a given cutter, in a direction tending exactly to the centre of the said wheel; and when the adjustment is made, and examined by the notch in gauge *p*, *fig.* 1, which ought to fall on the middle of the cutter, when turned round its centre of motion at its lower extremity, the tightening screws, *k* and *l*, may be turned home again, and the cutter will remain adjusted. With respect to the other advantage of cutting the bottom of each space in a straight line, however thick the required wheel may be, *fig.* 3 will furnish an explanation; here is a side view of the cutter seen less obliquely than in *fig.* 1, and detached from the other mechanism; H, as before, is the place, where the proper centre of motion of the arbor H I, in *fig.* 2, is, and R again is the cutter; the arbor of the cutter is hid, but can easily be apprehended to be admitted to pass up and down the opening *s t*, of the part, K, of the frame, as seen in *fig.* 1; while a roller or friction-wheel, surrounding the said arbor, touches the interior sides of the fork *s t*; this property of the cutter's ascending and descending in a straight line, when the handle, *s*, is raised or lowered, would however be checked by the limit of distance from R, the centre of the cutter, to H, the centre of motion; but the pieces, H and I, have also each a centre of motion at their lower extremities, as at *r*, which allow the centre H, and its corresponding one at I, to approach to, and recede from, the oblong aperture, *s t*, twice in each ascent and descent of the cutter; namely, once above its present horizontal position, and once below. The perpendicular screw at *u*, forms a stop to the ascent of the arbor, and a corresponding one below at *r*, forms a similar stop to its descent; the latter of which is also used as a limit for the depth of a contract wheel's teeth, during the operation of cutting. When a very large wheel is to be cut, there is a part of the cutter frame behind G, not seen, which is tapped, to receive the screw of the handle L, in *fig.* 1, one half of which tapped piece is cut away, and allows the other semicircular part to be set at liberty from the screw, by turning on a hinge, to enable the frame to slide freely to the rough distance, without turning the screw, which contributes to expedition in the adjustment of the cutter's distance from the solid arbor that bears the wheel. In common engines it may be proper just to mention the large plate O, together with its secondary frame that supports its lower pivot, is adjusted by the horizontal screw to the cutter, the frame of which cutter remains always fixed to the principal frame.

Besides the parts above described, the engine before us has got two appendages, that render its uses still more comprehensive, namely, a contrivance for cutting pinions on the arbor, and an apparatus for cutting straight racks, with which we will finish our account of this engine.

Fig. 1. of *Plate* III. (of Engines), is an elevation of the appendage for holding a pinion on its arbor, together with a section of the concentric tubes above the large plate referred to above, but not seen. In *fig.* 1. of *Plate* II. A B is a portion of the principal frame, denoted by the same letters as before, M and M, a section of the fixed tube M. In *fig.* 1. of *Plate* II., N and N, a section of the revolving tube N, or axis of the plate, P and P, its bearing shoulder, and Q R, a third tube, instead of the solid arbor, holding the pinion arbor fast, and fixed by the milled nut, R, under the plate O, seen now as a straight line: the stage of the innermost tube at Q, has many holes drilled into it, tapped so that not only a pinion, but a wheel also, may be attached to it, and cut, after it is fast to its arbor; of these tubes, Q, R, there are many varieties, differing in bore and size of the stage, to suit different purposes. The piece *a b*, attached to the frame A B, by two screws at *a*, has an oblong opening, receiving the sliding piece *c*, that can be fixed by a thumb-screw behind, at any height, and that admits the horizontal bar *d*, to slide through it, before it is fixed; at the part *e*, of *a b*, is a hole with a slit, that allows it to open or close by the action of the screw *f*; through this hole *e*, the steel wire, *g*, passes, and forms a bearing for the upper pivot of the arbor, *p*, of the pinion, which otherwise would yield to the cutter, while the bar *d*, pressing against the said arbor near the pinion, prevents its bending during the operation of being cut, or *slit*, as this operation is usually called, which is performed like the cutting of a wheel, already described.

Fig. 2. of *Plate* III. is a plan of the upper side of a small plate of brass, and of its appendages, for holding a rack during the act of cutting, and for limiting the size of the teeth to any given dimensions; *a b*, is the plate in question, mounted over the frame of the engine, near the cutter, by means of a strong bar, like *a b*, in *fig.* 1, and placed in the same situation, as may be seen in *fig.* 3, which is an end view of *fig.* 2; the two little screw-holes at each side of the letter *b*, in *fig.* 2, shew the place of attachment; and a strong screw, passing through the larger hole at *c*, enters the superior end of the main arbor of the engine plate, and fixes this mechanism steady enough to bear the action of the cutter, applied in the usual way. The bar to be cut into a straight rack lies upon this plate *a b*, from *d* to *e*, between the cocks *d* and *e*, on one side, and the adjustable bar *f*, on the other, which bar sliding in the two oblong openings, may be fixed at the required distance from the said cocks, by means of the two screws at its opposite ends taking into two nuts beneath, while a couple of thumb-screws *g*, *h*, seen in *fig.* 4, which is a side view, press above the said bar intended for the rack, and keep it firmly down. The pinion *i*, with twenty teeth, is used as the head of a micro-

meter screw, which the elastic index, *k*, rests upon, so as to make an audible sound, to serve as a reporter of each twentieth part of a revolution; it is seen in the *figs*. 2, 3, and 5, the last of which is the plane of the interior side of the plate *ab*, and without which the whole contrivance could not well be explained in an intelligible manner: on the arbor of the pinion, *i*, is an endless screw or worm, seen in *fig*. 5, into the spiral space of which a single tooth, *l*, is inserted; the bar, *l*, which is seen pressing against the cock *e*, as a thin bar in *fig*. 2, has a joint near the pinion *i*, on which the catch, *m*, turns, when lifted by the lever *n*, which lever itself turns on a pin in the bar *l*, as a fulcrum. The catch *m*, as represented in *figs*. 2 and 5, is raised a little from the bar *l*, and has a spring, attached to the bar *l*, pressing it back again into contact with this bar; consequently the end, *n*, of the lever is now nearer to the pinion, *i*, than it would be, if the end, *m*, of the catch were not removed, in opposition to its spring, from the excavated part of the plate. The catch, *m*, which is seen covering the bar, *l*, in the side view in *fig*. 4, has an oblong opening, through which the fixing thumb-screw, *o*, passes, as well as through an opening in *l*, not seen, into the cock *e*, in *fig*. 2; and the bar, *l*, is itself attached to the plate by a sliding cock *p*, in *fig*. 5, and also by a dove-tailed piece attached to the cock *e*, in *fig*. 2, on which piece the concealed dove-tailed opening of *l* slides, when the worm is in motion. From this detail of the different parts of action, it may now be conceived, that when the pinion, *i*, is turned, its worm actuates the single tooth attached to the bar *l*, and consequently moves this bar, together with the lever *n*, and catch *m*, a quantity in or out, that depends on the direction and quantity of the pinion's revolution, after which motion, it may be fixed to the cock *e* of the plate, by the fixing screw *o*; and as the edge of this cock *e* is divided into inches and tenths, a stroke made on the contiguous edge of the bar, *l*, serves as an index to measure the tenths passed over; the thread of the worm-screw is so cut, that one revolution of the pinion draws the bar *l*, and its appendages, just one-tenth of an inch: consequently, one tooth of the said pinion, counted by the noise of the elastic index *k*, measures $\frac{1}{20}$ of $\frac{1}{10}$, or $\frac{1}{200}$ of an inch. As the same letters of reference apply to all the four *figs*. 2, 3, 4, and 5, a further description, it is presumed, is unnecessary. In using this apparatus, the cutter-frame of the engine is adjusted so, that the cutter intended to be used is brought into contact with the edge of the bar to be cut, at the excavation near the end, *m*, of the catch, and is made to cut a notch, as though a wheel were to be cut; the cutter is then raised out of the notch thus cut to a proper depth, and the pinion, *i*, is turned, so as to make the end, *m*, of the catch fall into and fill the said notch, the rack being in the mean time pressed fast by the screws *g* and *h*, seen in *fig*. 4; the lever, *n*, is then depressed, which takes the catch, *m*, out of the notch; and supposing $\frac{1}{10}$ of an inch to be the thickness of the tooth to be cut, the pinion is turned back again two entire revolutions, one for the space, and the other for the tooth, in which new situation the bar, *l*, is set fast, by the fixing screw *o*; the rack is now set at liberty, by turning back the pressing screws *g* and *h*, and the rack is moved gently by hand, towards the pinion *i*, until the catch *m*, in its adjusted and fixed situation, falls again, by means of its spring, into the same notch which it occupied before it was moved by the worm-screw; the rack is a second time pressed by the screws *g* and *h*, and a second notch is cut as before, which now forms the tooth of a requisite thickness; again the catch, *m*, is lifted by the lever *n*, the rack set at liberty, and moved till the second notch is caught by the catch, where it is in a situation to be fixed for the cutting of the third notch, or second tooth; and thus the alternate process of raising the catch, and moving the bar of the rack, till it is caught in the next succeeding notch, is repeated before each cutting, till as many teeth are cut as are wanted; the pinion and its worm-screw having performed their whole office before the second notch was cut. When the rack is required to be cut into teeth on nearly its whole length, it is usual to begin about the middle, and to cut one half first, and then to reverse for the other half, and begin again from the notch first cut, which mode of operation requires not only the ends of the rack, but the surfaces also, to be reversed, after the first half of the work is performed.

On the plate of this engine there are thirty divided circles, with the points of division drilled quite through; numbered thus; 365, 360, 144, 100, 60, 30, 96, 90, 80, 78, 72, 54, 48, 62, 94, 92, 64, 59, 86, 88, 84, 82, 76, 74, 70, 68, 58, 56, 52, and 49, which divisions include all the usual numbers introduced in the wheels of clock-work; and such as are not found here may be obtained by the help of the micrometer, when wanted for planetary motions, or other extraordinay purposes.

Cutting Engine by Rehe.

Plate IV. *of Engines* exhibits a general perspective view of the engine for cutting the teeth of wheels, as originally made by Rehe for his own use, and which, we have said before, is now the property of Mr. Troughton of Fleet-street. It is drawn to one-fourth of the real size. AABCDE is one solid mass of cast-iron, formed into a frame in the mould, of which AA is the upper horizontal part, B and C the ends of the said frame, and DE its base, fixed with four strong screws (the heads of which are visible) to a wooden frame, to which the large wheel is appended, that gives motion to the revolving cutter and some intermediate pullies placed over the head to give a due direction to the moving cord: this large wheel and these pullies are purposely omitted in the drawing to give room for the engine itself to be taken on a good scale. F and G are a pair of cheeks forming a part of HI, which is another piece of cast-iron of the shape of a parallelogram, having an oblong aperture through the greatest part of its length, along the middle. KL is the platform, or large plate, of the engine, in which are drilled the dividing holes of a variety of circles; its diameter is nineteen inches; the arbor of this plate is a strong brass tube, MN, resting in a hole on the base, DE, of the large frame, and having a screw formed on its circumference at N, with a corresponding tapped nut, that has got a handle to turn it by; it has also a slit cut through it to admit a wedge under the nut, as may be seen without further description; the upper part of the arbor is supported by a hole in the top part of the frame AA, and passes freely through the oblong aperture of HI. The tubed arbor, MN, of the large plate will receive a variety of arbors successively, each of which has a slit to receive the wedge already named, near N, while the nut N, turned firmly down on the wedge, sets the interior arbor, that carries the wheel to be cut, fast at the shoulder O, on below its superior end. The interior arbor is, however, composed of two pieces, of which the upper part bears the wheel and is screwed fast into the lower part between M and O. There is a great variety of the upper parts of the interior arbor to suit different central holes of different wheels, as well as different shoulders, or resting places, for the wheels to lie upon in a steady manner, all which

would take feveral plates to reprefent, but may be eafily conceived to be only different fizes and fhapes of the fame thing; it may, notwithftanding, be right juft to remark, refpecting thefe bearing pieces of the arbor, that the centering of the wheel does not depend on the fcrew part that enters the concealed arbor, but on a circular bed, M, made at the top of the lower half of the arbor, which a correfponding circular piece of metal of the upper half, under the bearing fhoulder that holds the wheel, near O, exactly fits, by which means the wheel is certain to be placed in the centre of the large plate, which is an effential condition. The wheel, which is feen with a few notches cut, is faftened by a collet preffed down on its plane, by a tapped nut fcrewed from above the arbor. P Q is a brafs frame, embracing the folid cheeks G and F, and bearing the cutter and its arbor R, that has got a pulley on its pofterior end, round which the cord of the firft mover goes, and to which it gives the motion at firft produced by the foot; when the cutter is taken out to be changed, the end piece S, and a circular piece concealed at the oppofite pivot of the cutter arbor, are fet at liberty, by the tightening fcrews, T and T, being turned back *pro tempore;* a plan and fide view of one of the cutters, of which there is a great variety of fizes and fhapes, may be feen in *fig.* 2, of *Plate* VI., and the arbor difmounted and feparated into its parts in *fig.* 5, of *Plate* V., of one half its real fize, both which may be underftood by infpection of the figures, in the latter of which *a* is the pulley on the end of the arbor, *b* the part where the cutter is fixed by preffure of the tubed part *e*, urged by the nut *f*, when fcrewed home. When the hand U, in *Plate* IV., is turned, which has a pinion on its arbor taking into a ftraight rack, fixed to the part embracing the cheek C, out of fight, the whole brafs frame has a motion, up or down, as the handle may direct, which is always given it in the operation of cutting each notch. This motion of the whole cutter frame is made eafy and fmooth by eight fectoral pieces of hard polifhed fteel acting as friction wheels againft parallel bars, attached to the cheeks, both within and without the faid cheeks; of thefe fectoral pieces 1, 2, 3, and 4 are feen, but the others, placed in their oppofite and correfponding places, are concealed from the view, by the intervening parts of the mechanifm. Behind Q, on the pofterior part of the cutter frame, is a box containing a fpring, with a chain fixed at its lower end to a piece of metal, not feen, between the cheeks and behind the cutter frame, which fpring balances the weight of the frame in any pofition, and renders the working pleafant. Near the character 3 is a perpendicular fcrew feen, the lower end of which bears againft a folid piece fixed between the cheeks, when the frame is lowered fo much that the cutter is free from the wheel it is cutting; which fcrew is alfo the part of adjuftment for the exact depth of a fpace in a contrate wheel, while the barrel and chain limit the afcent. The whole of this cutter frame is attached to the horizontal parallelelogram HI, and is moved to or from the wheel to be cut, by a horizontal fcrew on the arbor of handle V, which enters a tapped part of the metal under the cutter frame, and when the due diftance for making the teeth of a proper depth is afcertained, the whole of the moveable part of the engine is fixed faft in its given pofition, by the clamping piece W, and croffed nut, that takes the fcrew on the upper end of a bolt, paffing up from below the top, A A, of the large fixed frame; the clamping piece, W, has a dove-tailed projection under it, that enters and fills the breadth of the oblong aperture of H I, and keeps the piece at right angles thereto. X is the fixing index, or index-bar with a fixing point, that holds the large plate in a given pofition: this index-bar flides into an octagonal focket Y, to which it is firmly fixed, when neceffary, by the thumb-fcrew feen under it; and near Y is a micrometer head divided into 30 divifions, for which a pin behind it forms an index; by means of this micrometer fcrew the fixing index can be made to protrude, or retire, any given fmall quantity, and when its fixing point refts in one of the drilled holes of the large plate, it confequently takes the plate along with it, and alfo the wheel fixed at the top of the plate's folid arbor. The focket Y has another octagonal hole at right angles to the former one, which enables it to flide along the octagonal axis Z, fo that the fixing point of X may approach to or recede from the centre of the plate, and be made to fall into any given divided circle; the numbers of each circle are laid down on the fmall oblong plate *a*, for which a line on the moving focket, Y, forms an index. This part of the apparatus belonging to the plate would have been fufficient, if the operator were to take the trouble of counting the holes of divifion on the plate as he turns it in the act of cutting; but in thofe cafes where every fecond, third, or fourth, &c. hole only is taken by the fixing point, in order to cut a wheel into one half, one third, one fourth, &c. part of the number laid down in any circle, fuch counting is very troublefome; therefore a curious addition of a moving index *b*, *c* is introduced to be a fubftitute for the counting. This index turns on the arbor of the large plate, and has a fliding point and thumb-fcrew *c*, to fix it in any given hole of the circle chofen for the fixing point of X to reft in: *d e* is a fliding ftop, paffing through a cock fixed to the part, A A, of the principal frame, and is held in any given fituation by the thumb-fcrew over it; and *f g* is another ftop attached to a fecond cock, fixed in like manner to A A; which fecond ftop can be placed in various pofitions, by means of its own flit and two thumb-fcrews, and alfo of the two flits in the cock at right angles to the length of the ftop. The ufe of the moving index is this; when the fixing point of X is faft in its proper hole of any given circle, the moving index is brought fo near to it, that its point will fall into the next contiguous, or fecond next hole, in which fituation the inner ftop, *d e*, is brought to bear againft it and fixed, then the moving index, *b c*, is removed back over two, three, four, or as many holes as are to be counted at each act of cutting a notch of the wheel, from the index X, and is put into the hole fo counted, in which fituation the outer ftop, *f g*, is brought to bear againft it and made faft; now it is eafy to conceive, that if one hand were to raife the fixing index, X, out of its hole, whilft the other hand were to bring the moving index together with the large plate into which it is inferted, until it meets with the inner ftop *d e*, the point of X would then cover the hole counted, into which it might be permitted to fall at random, and it would find its own proper hole under it; then raifing the moving index from its hole, and moving it to the outer ftop, would place it over the hole to be next counted, into which it might alfo fall at random. Thus the operation might be repeated all round any given circle, while the ftops would act as counters, and the moving index as a handle to move the plate by; but this mode of ufing the indices would occupy both the hands of the operator, and would require a fecond perfon to turn the handle U, and to attend to the cutter; an appendage therefore to the moving index is added, which connects

the moving with the fixing index in fuch a way, that one hand is competent to manage the whole operation even without the eye being directed to the part, after the ftops are properly fet, and the indices adjufted; thus, at the part *b* of the moving index is a milled head, like a thumb-fcrew in appearance, placed on the perpendicular fmall rod *b*, that paffes through this index freely, and attached to a lever *i*, that is moveable on a pin or centre of motion, at the inferior end of the cock *k*, placed faft to the moving index; this lever, *i*, paffes on, beyond its centre of motion, till it meets with a long lever under the plate, lying in the direction of the dotted lines paffing by K on the plate; this fecond or long lever is faft to the octagonal axis of focket Y, which, it has been faid, is alfo the axis of motion of the fixing index X; it is eafy then to fee, that, when lever *i* lies under the lever of the axis Z, pufhing down the milled head, *b*, over the moving index, will raife the fixing index out of its hole, on the large plate, and fet the plate at liberty to move; and alfo when the faid milled head, *b*, is quitted, the fixing index will fall again into the hole that may happen to be under it, and will be kept clofe by the fcrew *l*, preffing the long lever down by the intervention of the pin *m*, at its extreme end; all therefore that is neceffary to be obferved in moving the plate, after the indices and ftops are properly adjufted, is, to prefs with the thumb of the left hand on the nut *b*, before the moving index is carried forwards with the plate, and to let it go before the faid index is made to return without the plate, for an attention to this particular raifes and lowers the fixing index alternately in the way, and at the times required. When however a wheel is required to be cut into a number of teeth, not to be obtained from one of the divided circles alone, another operation becomes neceffary, to take or give a tooth or teeth to complete the number defired; this is done by the micrometer head of the focket, Y, of the fixing index, which will pufh the index out, or draw it in, any fmall affignable quantity, and will confequently pufh on or draw back the whole plate a correfponding quantity, provided the micrometer be turned when the fixing point of X is in its hole of the divided circle that is ufed; when this operation is neceffary at the cutting of every tooth, the moving index does not fall into a hole, but gradually advances to, or recedes from, its original fituation, till it arrives at the next contiguous hole, when one tooth only is to be added or fubtracted: but when more than one are required to complete the required number of teeth, the point of the moving index will gradually pafs over as many divided fpaces of the plate, from its original fituation, as there are teeth required to be added or fubtracted; fo that, if four teeth are to be gained or loft by means of the micrometer, the moving point will traverfe one divided fpace of the plate during the cutting of each quarter of the wheel, and in the fame proportion for any other number to be taken or given; whence, at any period, during the act of cutting a wheel into a number not inferted on the plate, it may be feen by infpection of the moving point, at what rate the gain or lofs is proceeding upon, which indication forms a good check upon the original calculation by which the micrometer is guided. This advantage, arifing from the point of the moving index having a progrefs or regrefs over the fupplementary divifions, is the more defirable in this engine; becaufe, the fixing index which ought to be always a tangent to the divided circle ufed, and to have its point at a right angle to the central arbor of the plate, does not preferve the latter condition rigidly, when pufhed out or drawn in; which deviation renders the reading of the micrometer in practice, lefs accurate than the theory fuppofes; an objection from which the more complex mechanifm of Hindley's engine is free. When a wheel of 142 teeth was cut on our prefent engine, in our prefence, from a divided circle of 140, nineteen turns of the micrometer were found equal to a motion of two divided fpaces, as compared with the moving point, when left ftationary againft the outer ftop: therefore, as there are 30 divifions on the micrometer head at Y; 19×30, or 570, were the whole divifions to be divided by the number 142, and gave a quotient of 4, with a remainder of $\frac{2}{142}$; confequently, after every moving of the plate for a new cutting, four divifions of the micrometer head were turned in a backward direction, to leffen the fize of the teeth, and to increafe their number in the proportion 142 : 140; but at two oppofite points of the wheel, the remaining two were interpolated, by giving five divifions inftead of four at each place; the additional divifion on the micrometer, however, made at each of the faid two places, made no fenfible difference in the fize of thofe teeth, nor would it have been of any importance, if the remainder, which was fo fmall, had been neglected altogether. A fimilar procefs, as explained more fully in our account of Hindley's engine, muft be adopted agreeably to a fimilar calculation, for any other number of teeth to be taken in or left out by the aid of the micrometer. The original circles of the large plate were divided by Troughton's dividing-engine into the following numbers, *viz*. 720, 580, 504, 396, 365, 364, 300, 276, 228, 192, 186, 170, 162, 156, 140, 128, and 118; to which have been fince added, at different times, the numbers 274, 260, 206, 148, 136, 130, 111, 103, 101, 87, 83, 74, 65, 47, 43, 41, and 37, fo that, by this engine, all numbers under 100 can be cut without the help of the micrometer, except 97, 95, 89, 88, 79, 77, 61, 53, and 49.

When our prefent engine is ufed to cut pinions on their arbors, a fteel perpendicular bar defcends from a beam in the room directly over the centre of the plate, and holds the upper end of the arbor fteady, while the lower end is made faft to the revolving arbor. There are alfo many other ufeful appendages to the engine, fome of which merit a particular defcription and correfponding drawings, which we have obtained.

Fig. 1, of *Plate* V. is a detached cutter frame of one-fourth of the real fize, to be ufed occafionally when a wheel is wanted to act with a worm-fcrew, in which cafe the teeth are required to be a little inclined from the axis to the right or left, accordingly as the fcrew is a right or left-handed fcrew. When this cutter frame is ufed, it is attached to the cheeks G, F, in *Plate* IV., without difturbing the frame already attached. A B is a ftrong brafs plate with two forked pieces, C, D, projecting back from its pofterior plane near the top; thefe forks enter over the fliding frame S Q, in *Plate* IV., and embrace the two tapped ftuds *n* and *p* not feen, within the cheek, by which they are held faft when preffed by the tapped nuts of the faid ftuds; at A, the bottom of the plate A B, in *fig*. 1, of *Plate* V., is a fcrew which enters the fmall tapped hole, near I, on the fliding piece H I, in *Plate* IV., and a correfponding fcrew at the other fide, out of fight, holds the fourth or concealed corner of the faid plate A B, fo that this plate, when thus attached, may be confidered as a part of H I, in *Plate* IV., behind which additional plate the common cutter frame is concealed, and remains ufelefs for the time. E F is a fecond plate of brafs of nearly a femicircular fhape and graduated on its periphery; this fecond plate is attached to the former one, A B, by two tapped bolts paffing through the long opening G, and made faft with nuts at E and F, by which

means this fecond plate can be placed at any given height on A B, and a motion, which it has round E, as a centre, allows of its being placed to any angle of obliquity marked on its periphery; the circular flit at E, allowing the upper or fixing bolt to pafs along it to any required pofition, before it is fixed by the nut: the cutter frame, H I K L, moves on pivots in the feet of E F, near A and K, which pivots are turned out of an horizontal line to the right or left, by the obliquity given to the plate E F, and confequently the cutter arbor, L I, has alfo an obliquity, which makes the cutter at the middle of it cut the notches in an oblique direction; this cutter, however, having but one centre of motion, or rather one pair of centres, cuts the bottom of the notches of a wheel in a circular direction. The arbor of the cutter has a pulley which gives it motion, and the two pulleys, *a* and *b*, over it have no other ufe, but to direct the cord to the larger diftant pullies, not fhewn in the drawing. When the plate, E F, is adjufted to zero, or horizontal line, it may be ufed for cutting ordinary wheels, but is liable to be difplaced by accident or jerks in cutting; therefore is ufed only for wheels with oblique teeth. The French engine recommended by Berthoud, as made by Hugot has, notwithftanding, no other cutter frame but that which is adjuftable for obliquity. The vertical fcrew, *d*, is a reft for limiting the depth of the fpaces of contrate wheels in cutting, and alfo for ftopping the defcent of the frame further than is neceffary in cutting other wheels: the opening B of the plate A B feems to have no other ufe, except for the eye to look through at the cutter, when the workman ftands behind the cheeks to turn the firft moving wheel of the cord, which wheel, we remarked, is not very conveniently placed to confult the eafy pofition of the body, during the act of cutting. This frame being attached to the fliding part H I, of *Plate* IV., is of courfe capable of the adjuftment for diftance from the arbor of the plate, on which the wheel is placed, that requires to be cut.

Fig. 2, of *Plate* V. is a reprefentation of the apparatus for cutting the interior edge of an annular wheel, fuch as is ufed in a theodolite, and folar microfcope, &c. of ½ of the actual fize. A B is the ring or annular wheel to be cut, which is fixed to the top of the arbor by means of the wooden chuck, on which it was turned in the lathe, and *a b c d* is a fhort frame for the cutter *e*, and cutter-arbor, feen detached in two pieces in *fig.* 3 of ½ the real fize. This fmall frame is attached to the face of the cutter frame in *Plate* IV.; its arbor, *a b*, enters the hole of the arbor at S, and an oppofite hole not feen in *Plate* IV., after the arbor, R, has been previoufly removed, and is made faft by the two fcrews *x* and *x*, entering the holes *c* and *d*, of *fig.* 2. *Plate* V.; the interior teeth are then formed by the fmall cutter, by a procefs fimilar to that of cutting the exterior teeth of a wheel in the ordinary way.

Fig. 4, of *Plate* V. is a contrivance of ¼ of the real fize, for cutting a rack into any number of teeth per inch, by the aid of the engine plate and common cutters, thus; A and B are two ftrong cocks fcrewed faft to the oppofite fides of H I, already defcribed in *Plate* IV.; C is a piece of metal forming a bed for the oblong bar, D E, to reft on; this bar, which is a rack already cut, is placed with its teeth in action with a wheel of 74 teeth nicely rounded, that is attached to the arbor of the plate in the ufual way; under the bar D E, and faft to it, is a rib parallel to its fides, moving eafy in a correfponding long groove made in the bed, C, to receive it, the motion of which is made fmooth by friction wheels interpofed and borne by the bed; the bar, D E, has a great number of holes drilled and tapped in it, that the moveable corks or clamping pieces, F, F, and F, may fix any bar, G, to be cut into the requifite rack; when the mechanifm is thus arranged and properly fixed, the motion of the wheel, caufed by moving the fubjacent plate, a given number of holes of any circle fixed on, will carry the racked bar D E, and bar G along with it, over the bed a certain diftance, between the cutting of each fpace of bar G, and this diftance may be made $\frac{1}{10}$th, $\frac{1}{15}$th, or $\frac{1}{20}$th of an inch, according to the number of divided holes on the plate, paffed over by the moving index, between each operation of cutting.

Thefe three appendages render the engine competent to cut teeth in all ways, and on all wheels and bars that are in ufe in mechanical contrivances; but the teeth thus formed with ordinary cutters, are in the fhape of parallelograms, and require to be rounded by hand with a file or files of different coarfenefs and fhape; the contriver, in common with other workmen, had experienced the inconvenience attending the finifhing, both as it was a laborious operation, and liable to produce irregularities in the fhape of the tooth, on which the equable tranfmiffion of power and velocity entirely depend, in clocks, watches, and other delicate machines; he therefore conftructed his cutters in fuch a way, that they rounded the teeth at the fame time that they cut the fpaces; this invention is very important to the fuccefsful application of racks and wheel-work in many cafes, where a good fhape of the tooth is indifpenfable, and has been claimed by both Rehe and the late ingenious Merlin; but which of the two, if either, was the real inventor, remains to be decided.

Plate VI. *of Engines*, contains the drawings of fome cutters to anfwer the purpofe of rounding the teeth during the act of cutting, and alfo the apparatus for forming the cutting edges and for fharpening them when blunt, which apparatus is indifpenfably neceffary to accompany the engine when *finifhing cutters*, as we fhall henceforth call them, are adopted in practice.

A A, in *fig.* 1, is the front fide of a wooden bench, to which a foot wheel, as a firft mover, is fixed out of the drawing, and B B is a fmall frame attached to its inferior plane; C C C is a fpecies of fmall lathe, with a three-grooved pulley revolving on a folid arbor, together with the arbor itfelf; this lathe is attached to the brafs plate D D, and by means of it fcrewed faft to the wooden bench A A; at the exterior end of the arbor that bears the pulley, is fixed a circular copper plate, E, with its plane at right angles to the faid arbor, which plate confequently revolves with the pulley, when the foot wheel gives motion to the cord that embraces it: juft above the brafs plate, D D, of the fmall lathe, lies parallel thereto another ftronger but fmaller plate, F F, attached to and borne by a fide plate, G G G G, that fits the frame under the bench, and flides up or down to nearly the height required in ufe, in which it is fixed by the thumb fcrew at H, under the bench; at the ends of the plate F F, which we will call the bed of the cutter frame, or frame for holding the cutter while grinding, are two crofs bearing pieces near F and F refpectively, on each of which are cut three femicircular notches, fome of which are feen at *a*, *a*, and *a*; I I is the horizontal plate of a cutter frame refting on the horizontal tapped wire, K, that has got a milled nut fcrewing upon the tapped part beyond the bed F F, and has its oppofite bearing end concealed under the other parts; this plate, I I, may be fixed to any part of the bearing wire, K, by the thumb fcrew *b*, and will have a little circular motion round the wire, to the right or left, when not held in the

hand, or nicely balanced; above this plate, I I, lies a ftill fmaller plate, L, that bears the cock M, and another fimilar one concealed, but oppofite to it; which fmall plate, L, is moveable round a centre of motion under it, on the next fubjacent plate I I, but can be fixed in any given pofition by the thumb fcrew at L, agreeably to the graduations marked near its extreme end, beyond the circular groove penetrated by the thumb-fcrew, for which graduations a line on the fmall cock, *d*, conftitutes an index: into the cock M, and the one concealed, paffes an arbor not feen, that may be called *e*, which is capable of being fixed by preffing fcrews at the exterior fides of the faid cocks; acrofs this arbor, *e*, at right angles, is a long hole, or tube, into which the cutter arbor is inferted, and fixed by a preffing fcrew N; fo that the plane of the cutter may be made either horizontally parallel to the copper circle E, or to ftand in an inclined direction: accordingly as the arbor, *e*, is turned more or lefs round before it is fixed by its preffing fcrews at M, and at the oppofite pivot; while the thumb fcrew at L, by the help of the graduations near it, fixes the planes of the cutter and circular plate, E, vertically parallel, or at any given angle of reclination to each other, as the fhape of the acting faces of the tooth may require; the nut at D limits the proximity of the cutter to the circle E. In the prefent pofition of the cutter, its plane is fmoothed by emery fmeared over the copper circle, as the arbor revolves, and while the plate, I I, has a circular motion given it backwards and forwards by hand, round the bearing wire K, which alternate motion carries the cutter acrofs the plane of the grinding circle E, and affifts the grinding; upon the arbor *e*, not feen, is a fecond divided fcale of a circular fhape, like a micrometer head, by means of which the fituation of this arbor, and confequently of the cutter's plane, is adjufted before the preffing fcrews are made quite faft; and a fmall gauge, near *f*, like a fmall leg and foot, moveable at its knee, on the cock, prefents its heel to a tooth of the cutter, and limits its pofition in fuch a way, that each fucceeding tooth to be fharpened may be fixed, by the preffing fcrews, in precifely the fame fituation while they are refpectively fharpened. By the help of thefe various adjuftments of the plane of a cutter, fuch, for inftance, as is feen in two views in *fig.* 2, the preceding or cutting part of each tooth is made thicker than the following part, and alfo the part at the periphery thicker than the part nearer to the centre, which fhape makes the cutter clear itfelf in the fpace it cuts as it advances, a condition that experience has proved to be neceffary in forming or fharpening a cutter When one plane of each tooth of a cutter has been gone round, the planes are reverfed, and the cutter fixed as before by the help of the fcales, gauge, and fcrews, and then the former procefs of grinding the teeth fingly in fucceffion is repeated.

When the plate I I, with its appendage, which together we have called the cutter frame, is lifted out of the femicircular notches or bearings on the ends of the bed F F, and is laid afide; another nearly fimilar frame, feen in *fig.* 3, is put into its place, with the parallel wires, *a*, *a*, and *a*, refting in the faid femicircular notches, as in *fig.* 1, are denoted by the fame characters; in this fituation the nut, D, in *fig.* 3, falls in the place of nut D in *fig.* 1, and anfwers the fame purpofe of adjuftment for proximity of the cutter to the grinding circle E; the fmall upper plate, L, is alfo nearly the fame as in *fig.* 1, both as to its pofitions and ufes, where alfo the index line of the fmall cock, *d*, points out the degree of obliquity on the graduated fectoral part; but here the frame is not a fingle plate I I, refting on the bed as in *fig.* 1, but has a motion round the pivots *h* and *h*, placed on another plate that bears the wires *a*, *a*, and *a*, fo that the two plates may be made to open, and form a blunt wedge, by turning the fcrew *k*, which bears on the lower plate with its point, and is tapped into the upper plate, after which adjuftment for height, which cannot be made nicely by fliding G G G G only, the pofition is rendered permanent by the fixing nut, *l*, that takes a tapped ftud fixed to the lower plate. In this figure, the arbor that holds the cutter is in the fituation of the arbor *e*, *fig.* 1, which we faid cannot be feen; and the ends of the teeth are prefented to the grinding face of E, which pofition of the cutter could not be attained by the mechanifm of *fig.* 1. On the cocks that bear the pivots of the cutter arbor, are fixed two fmall cannons, on which the bent arms, *m* and *m*, revolve, and are fixed by the preffing fcrews *n* and *n*; the play of the arbor is limited by the two thumb-fcrews *o* and *o*, fixing the ftops in their refpective places; and a wire, *k*, connected with the arms *m* and *m*, forms the centre of motion of the leg or gauge, which is here better feen than in *fig.* 1, and performs a fimilar office. It is hardly neceffary to add, that after each tooth is pointed in this way, the fixing fcrews *m* and *m*, and alfo the gauge *f*, are releafed for the moment, and brought back again to their original fituation at the adjuftment of every fucceffive tooth to the grinder.

For fharpening the front edge of a tooth, the cutter muft be reverfed, the bed lowered, and the nut, D, turned back, till the pofition, reprefented in *fig.* 4, be obtained; in which the teeth are fuceffively ground as before directed.

The mechanifm above defcribed is all that would be neceffary, if the tooth of the cutter were made by ftraight lines to cut teeth of a fhape like a parallelogram, but to round them at the fame time required another addition, which remains to be defcribed.

In *fig.* 5, are feen two different views of a cutter, fuch as will round the teeth and cut them at the fame operation, by means of the fides of the cutter's teeth being formed into curves; thefe curves ought to be epicycloids, or involutes of a circle to conftitute a tooth of any wheel of the exact fhape requifite for the equable tranfmiffion of power and velocity, and thefe curves fhould vary in fhape with the fize of the wheel compared with its pinion or fellow-wheel; but fuch niceties cannot be obtained in practice without almoft infinite trouble; therefore the fame cutter, once fhaped and fharpened, is ufed for wheels of different diameters, where its thicknefs is found proper. *Fig.* 6, fhews how the fide curves of the cutter's teeth are formed, where a cylinder of copper is fubftituted in the fmall lathe C C C, *fig.* 1, for the arbor and circular plate E; *fig.* 3, is then applied to the bed F F, and the fide of the tooth is adjufted to touch the fide of the cylinder as it revolves; this mode of application would make the curve circular if the cutter-arbor were to ftand at right angles with the grinding cylinder; but as any degree of obliquity can be given, by undoing the thumb-fcrew *b*, and moving L, the pofition ought to be fuch as to make the tooth reft obliquely againft the cylinder, more or lefs, as the fhape may require, in which cafe an elliptic curve, inftead of a circular one, is formed on the edge of the cutter, by reafon of the oblique fection of a cylinder forming an ellipfe, which curve approximates nearly to the fhape required in a given degree of obliquity, and may always be ufed when once determined. When the curves on one fide of each tooth of the cutter are thus formed, which are affifted by a motion lengthwife of the frame in the bed, while the wires *a*, *a*, and *a*, flide in their bearing notches, the planes of the

cutter are reverfed and the oppofite correfponding curves are formed in a fimilar manner. Cutters of this kind not only facilitate the labour of making wheels, but render them more perfect than manual filing can poffibly do; and it is to be regretted that clockmakers in general will not go to the additional expence of having them thus formed. Thus, each of the two engines we have defcribed, have appropriate advantages; and we think it would not be difficult to conftruct one that would unite the advantages of both, and be preferable to either.

Cutting Engine by Hindley.

Fig. 2.

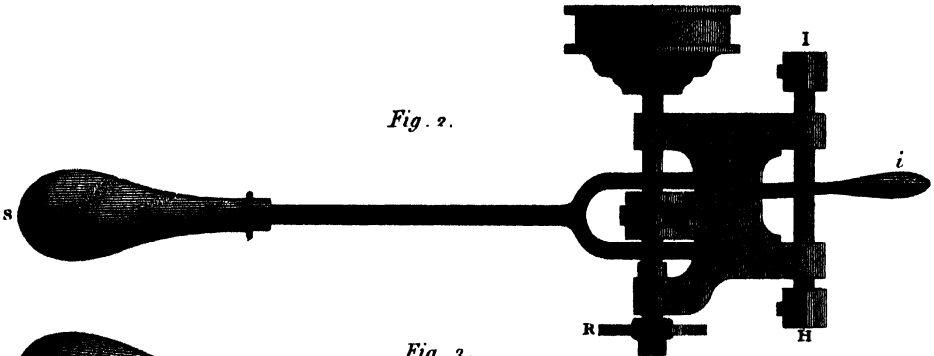


Fig. 3.

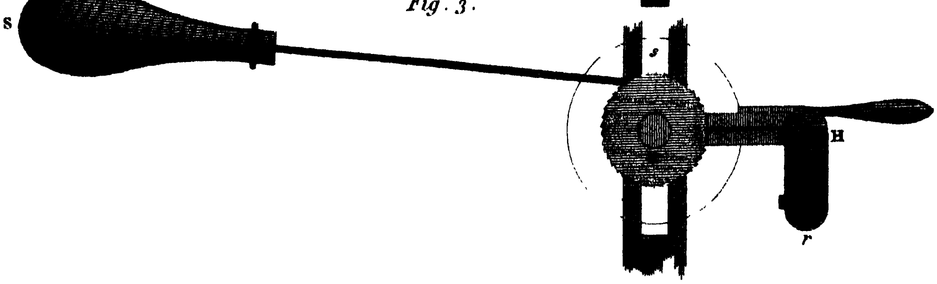
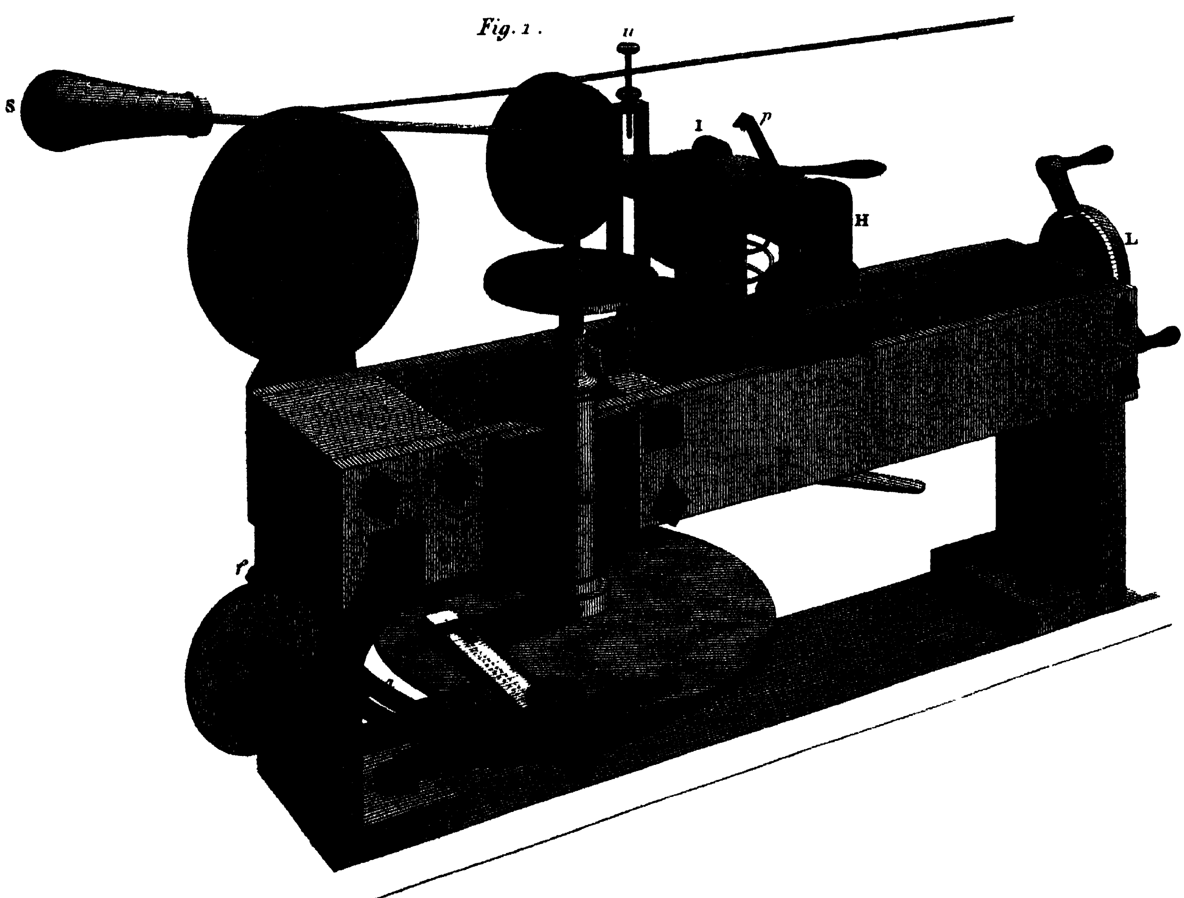


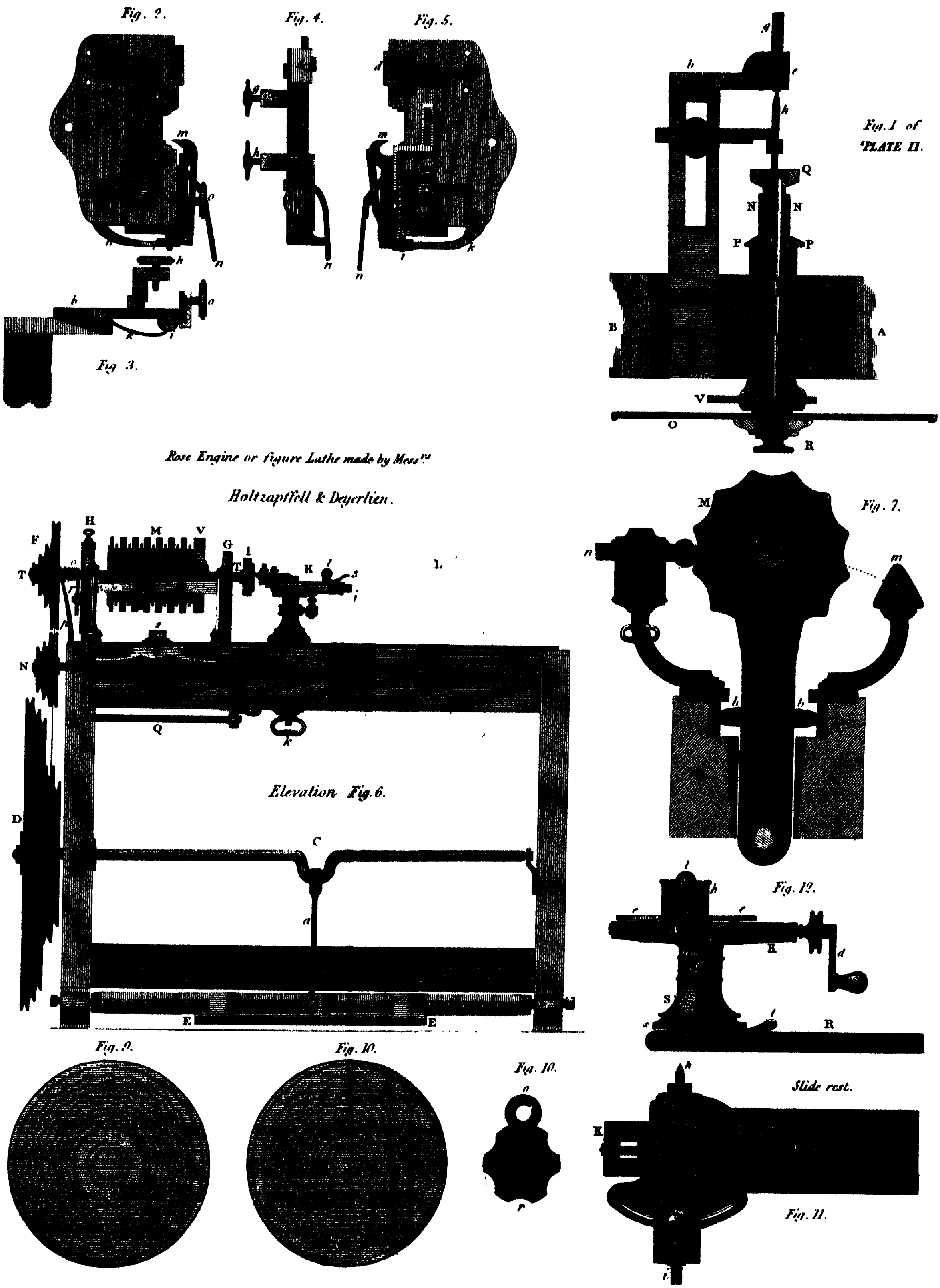
Fig. 1.



J. Farey Junr. delin. *Published as the Act directs, 1813, by Longman, Hurst, Rees & Co. Paternoster Row.* *Engraved by W. Lowry.*

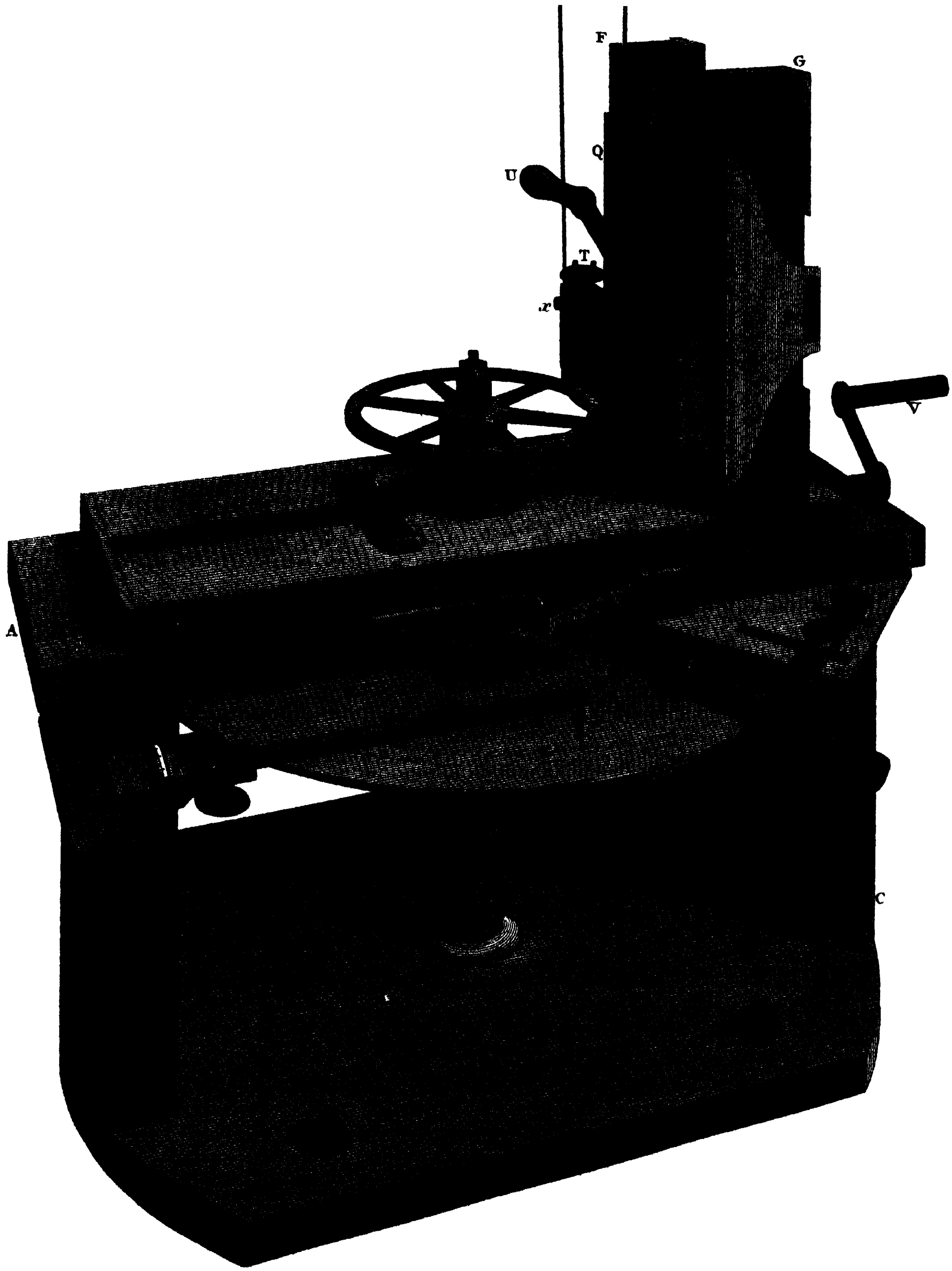
ENGINES.

CUTTING ENGINE



J. Farey Junr. delin.
Published as the Act directs, 1816, by Longman, Hurst, Rees, Orme, & Brown, Paternoster Row.
Lowry Sc.

cutting ENGINE by Rehi.

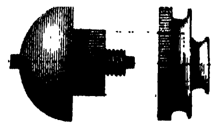


Drawn by J. Farey Junr., from the original ½ real size. *Published as the Act directs, 1817, by Longman, Hurst, Rees & Co. Paternoster Row.* *Engraved by Lowry.*

CUTTING ENGINE by REHE.

Fig. 3.

Short arbor



For worm wheels

Fig. 1.

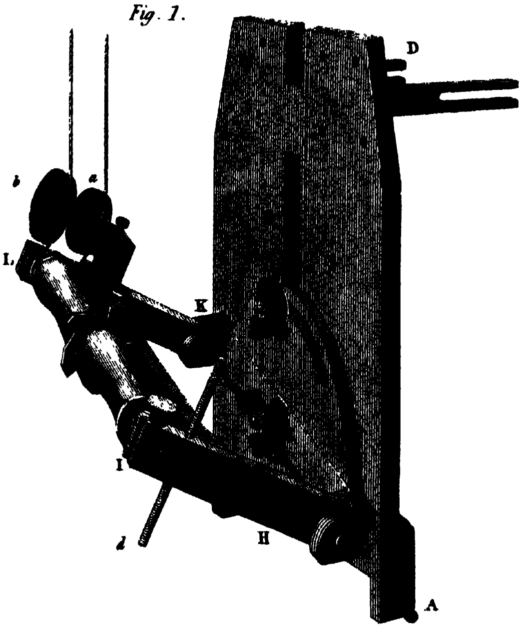


Fig. 2.

For annular wheels

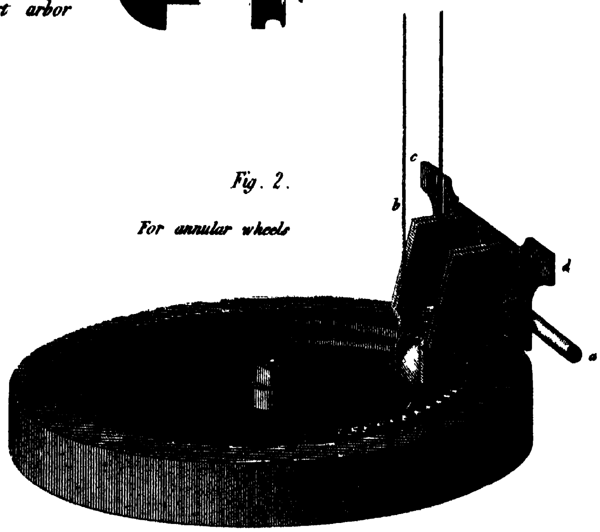


Fig. 4.

For Racks

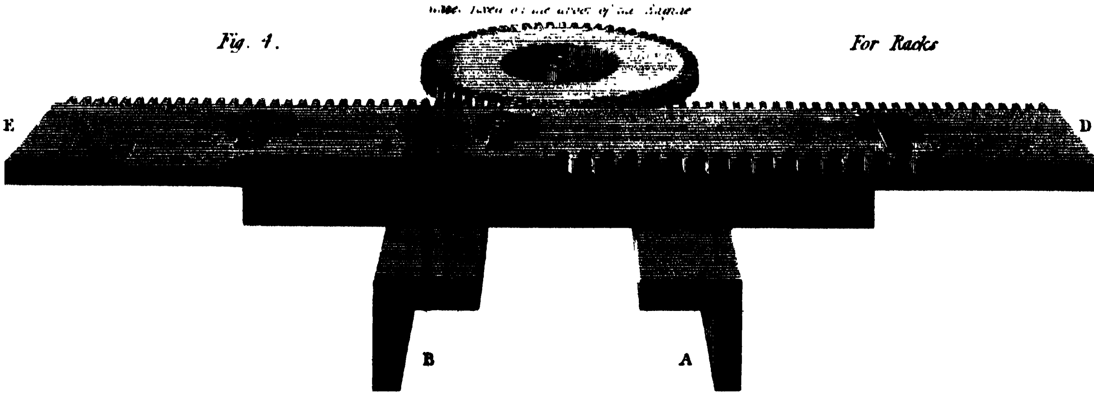
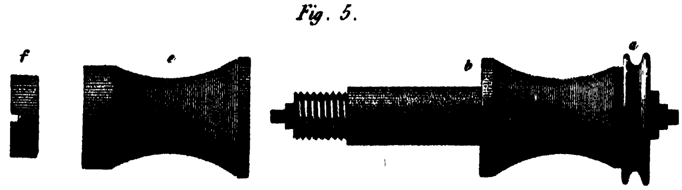


Fig. 5.

Cutter arbor



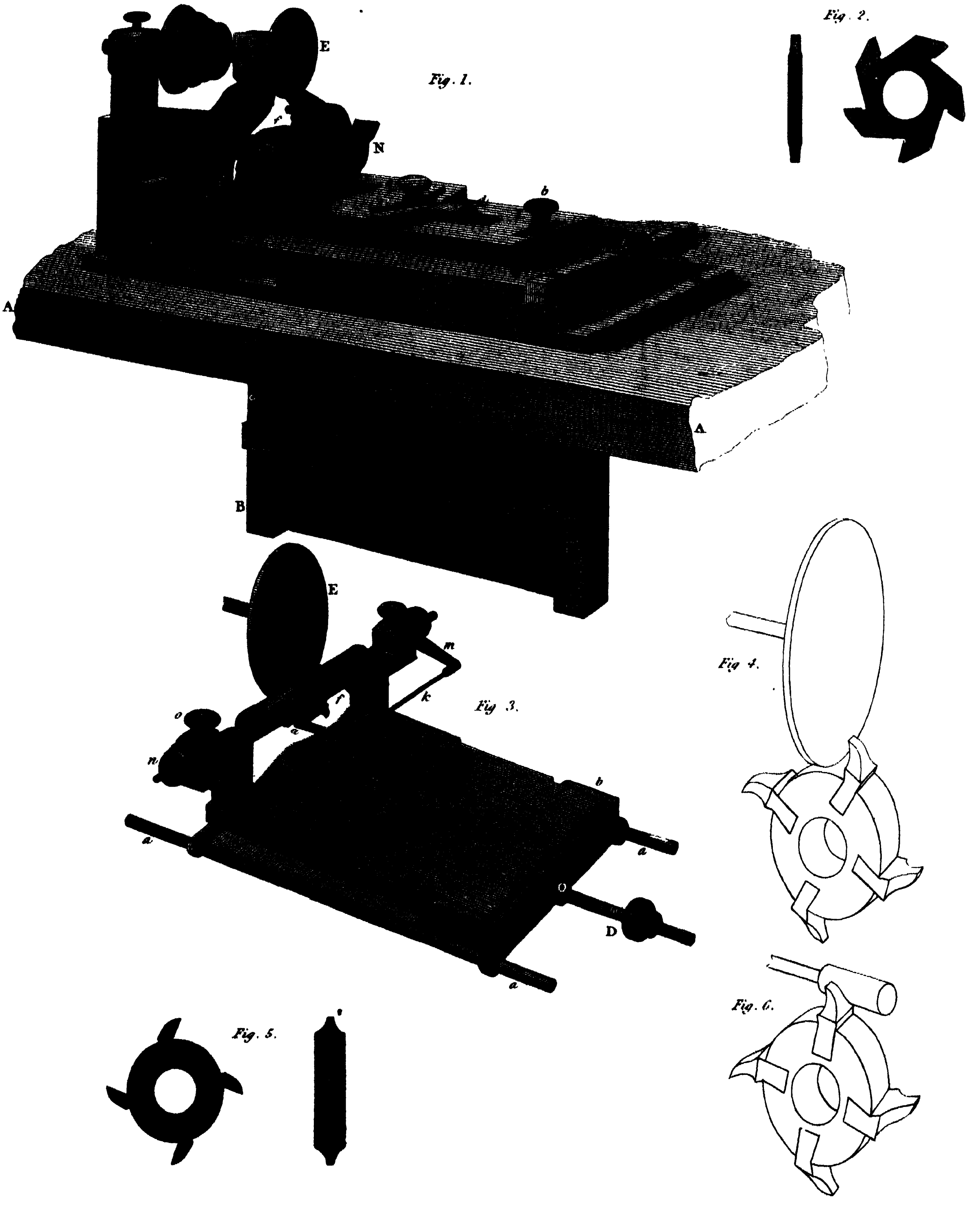
Farey delin. *Published as the Act directs, 1818 by Longman, Hurst, Rees Orme & Bro* *Lowry Scu*

ENGINES.

For sharpening Cutters,

BY REHE.

PLATE VI.



Lowry Sc.

Cyder

CYDER, in *Rural Economy*, is a fruit liquor prepared by means of fermentation, from the expressed juice of different sorts of apples. The process by which this liquor is formed has much similarity in all the different districts where it constitutes an object of the farmer, though there is much diversity in regard to the care and management which are bestowed upon it.

The varieties of apples which are grown and cultivated in the various fruit districts of the kingdom, with this intention, are extremely numerous; but by some it is supposed that all such as have a yellow or light red ground, are tinged with red streaks on the sun side, having a smart acid flavour, with a firm juicy parenchyma and an aromatic flavour, whatever the name may be, are unquestionably proper for cyder. It has, however, been remarked by Mr. Knight, that the properties which are essential for cyder and the table are rarely met with in the same fruit. That degree of firmness which is necessary in the eating apple, is useless in the cyder fruit; and colour, which is disregarded in the former, is amongst the most important qualities of the latter. Some degree of astringency, which is prejudicial in the eating

fruit, is conceived beneficial in that made use of for cyder. In Devonshire, according to Mr. Vancouver's Survey, a rich sweet fruit is generally preferred for the purpose of cyder, while in others those which have more astringency are held in the highest estimation. See Apple, Apple-tree and Orchard.

Gathering the Fruit.—In the business of gathering the fruit for this liquor, much care should be taken that it be sufficiently ripe before it is removed from the trees, otherwise the cyder will be harsh, rough, and unpleasant in its taste, in spite of any thing that can be done in the process of making it. The most certain indications of ripeness, according to Mr. Crocker, are the fragrance of the smell, and the dropping of the apples from the trees in a spontaneous manner.

The most early ripe fruits should, of course, be first gathered, but as on the same trees the fruits rarely become equally ripe at the same period of time, it is found necess. to throw them together into large round heaps in the open air, as noticed below, in which state they are suffered to continue for some time, until a sort of sweating or fermentation has been brought on, which induces a similar state of mellowness and fitness for grinding in the whole heap. This method, however, which requires much judgment in directing it, does not, even under the most careful management, always answer the purpose; therefore the nearer the apples approach towards perfect ripeness the better, as their juice is the more rich.

Mr. Crocker advises that in a dry day, when the fruit has acquired such a state of maturity as to be ready to drop from the tree, that the limbs or branches of it should be slightly shaken, and disburthened in a partial manner of its apples, thus taking only such as are in a ripe state, leaving the others to acquire a due degree of maturity. It is indeed suggested as proper to make three gatherings of the crop, keeping each of them by itself.

The latter gatherings, as well as the wind-falls, can, however, only be employed in making inferior cyder: the prime cyder must be drawn from the first gatherings which have been made.

According to Mr. Knight, the merit of cyder will always depend much on the proper mixture, or rather on the proper separation of the fruits. Those whose rinds and pulp are tinged with green, or red without any mixture of yellow, as that colour will disappear in the first stages of fermentation, should be carefully kept apart from such as are yellow, or yellow intermixed with red. The latter kinds, which should remain on the trees till ripe enough to fall without being much shaken, are alone capable of making fine cyder. Each kind should be collected separately, as noticed above, and kept till it becomes perfectly mellow. For this purpose, in the common practice of the country, they are, as stated above, placed in heaps of ten inches or a foot thick, and exposed to the sun and air, and rain; not being overcovered except in very severe frosts. The strength and flavour of the future liquor are however, he says, increased, by keeping the fruit under cover some time before it is ground; but unless a situation can be afforded it, in which it is exposed to a free current of air, and where it can be spread very thin, it is apt to contract an unpleasant smell, which will much affect the cyder produced from it. Few farms are provided with proper buildings for this purpose on a large scale, and the improvement of the liquor will not nearly pay the expence of erecting them. It may reasonably be supposed that much water is absorbed by the fruit in a rainy season; but the quantity of juice yielded by any given quantity of fruit will be found to diminish as it becomes more mellow; even in very wet weather, provided it be ground when thoroughly dry. The advantages therefore, of covering the fruit, will probably be much less than may at first sight be expected. No criterion appears, the writer says, to be known, by which the most proper point of maturity in the fruit can be ascertained with accuracy; but he has good reason to believe that it improves as long as it continues to acquire a deeper shade of yellow. Each heap should be examined prior to its being ground, and any decayed or green fruit carefully taken away. The expence of this will, he observes, be very small, and will be amply repaid by the excellence of the liquor, and the care with which too great a degree of fermentation may be prevented in the process of making it into cyder.

Mr. Crocker has likewise remarked that the cyderist, who would be particularly curious in his prime liquor, should hand-gather his fruit, and keep the sorts separate one from another: but as this would be troublesome, expensive, and in a full season wholly impracticable, the general crop may, at different times, be shaken down, and collected from the ground. Fruit of equal ripeness, and whose qualities are nearly alike, should be heaped together, to meliorate their juices, or, in other words, to perfect the saccharine fermentation. How this is best done, cyder-makers are not, the writer says, agreed: some, says he, judging it altogether unnecessary to keep them at all, if sufficient time be allowed for perfecting the saccharine fermentation on the tree: some considering it best to sweat them in close lofts, whilst others allege, that the open air is the only place where they ought to be heaped. Experience, however, should, he thinks, teach us that most apples require time for their being mellowed, to attain their highest flavour; and, until this mellowing be perfected, their juices are not in the best state possible for being converted into cyder-liquor.

However, philosophy has shewn, he thinks, that fermentation is never improved by hastening the operation with too much heat; nor perfected in due time under too great an exposure to cold. It would be well, therefore, says he, if apples, when gathered from the tree, were placed in open sheds, having boarded floors, in heaps or layers of ten or twelve inches deep; the hard and harsh fruits might probably, he supposes, be laid in heaps of greater depth; the sorts to be kept separate, as much as the nature and conveniences of the sheds will allow: at any rate there must be a mixture of apples in the same heap; let them, says the writer, be such as are of qualities nearly alike, and which are of equal ripeness at the time of gathering, but on no account should sweet and sour fruit be heaped together. To some cyderists it may, says he, have appeared unnecessary to keep the different sorts of apples separate, but it is of importance so to do: and the trouble is very little, as has been observed, compared to the advantages which will hereafter result from a regular fermentation of the juices. The impropriety of housing and laying apples in very large heaps must, the writer thinks, be manifest to every thinking mind; more especially when in the same room are found all sorts; sweet, sour, harsh, generous, ripe, and unripe, thrown promiscuously together; where some are rotten before others are mellowed. And what must the liquor be, he asks, which is expressed from such an heterogeneous mass?

In respect to heaping, the author of the Survey of Gloucestershire well remarks, that though it may improve unripe fruit, it cannot communicate the richness found in that which is fully ripened. And that the effect which is thus produced on those which are heaped in a very green

and unripe ſtate, is rottenneſs, in which condition very few are capable of communicating an unpleaſant flavour, even to a very large quantity of the liquor, eſpecially where they have become of a black appearance.

Suppoſing, ſays Mr. Crocker, that the fruit, which is of different ſorts and qualities, has been kept ſeparate from one another a few weeks, it will be perceived that ſome of the prime ſorts are in a proper ſtate of maturation; that the pulp has acquired its higheſt degree of richneſs; the kernels aſſumed their browneſt colour; the rind ſtill free from any appearance of rottenneſs; and that they readily yield to the preſſure of the thumb: then is the time, ſays he, and ſuch is the fruit to be employed in making prime cyder: every neceſſary utenſil muſt now be ſet in order: the mill, preſs, tubs, caſks, pails, and bowls, clean waſhed, and ſuffered to dry before they are employed in the buſineſs.

The able writer of the Agricultural Report of the County of Glouceſter very ſtrongly and very juſtly reprobates the too common practice of thoſe who indiſcriminately, and without any regard to the maturity of the fruit "run over the whole orchard with the beating pole, or 'lug' and bring down every apple within their reach," as thus beating the trees before the fruit is nearly ripe is not only injudicious in reſpect to the cyder, but injurious to the ſucceeding year's crop of fruit; the bearing buds for the next ſeaſon being formed early in the ſummer near, and even attached to, the growing fruits. Of courſe, the beating of the trees, unleſs where the apples ſeparate with facility, muſt of neceſſity bring off the buds which nature had provided for the enſuing year, with them. And he adds that, "after an operation of this kind the ground is ſtrewed with theſe buds, to an extent ſcarcely to be conceived by thoſe who have not witneſſed it." The practice of the moſt careful farmer is therefore, he ſays, to have the trees "ſhaken limb by limb, by a perſon up in the tree," only ſuffering the few that remain to be beaten off, and occaſionally even allowing them more time to ripen, which he conſiders by far the beſt practice, except that of ſuffering them to fall of their own accord, as ſecuring a regular fermentation with leſs keeping.

Grinding the Apples. In the buſineſs of grinding the fruit for this uſe, into what is termed pommage, ſeveral different methods are practiſed: but thoſe moſt commonly in uſe are the bruiſing-ſtone, with a circular trough, and the apple-mill. In the firſt of theſe methods the apples are thrown into the trough, and bruiſed by the motion of the ſtone, as it is moved round by a horſe, in the uſual way that tanners grind their bark. This is a very ancient method, and which is ſtill in uſe in ſome parts of Devonſhire; and although it has its inconveniences, in bruiſing ſome apples too much and ſome too little, it is not without its advocates in theſe parts of the country; the inhabitants of which allege, that it bruiſes the kernels of the fruit better than other machines. Although it muſt be admitted, that the kernels poſſeſs an agreeable aromatic bitter, yet it has been held queſtionable if they impart any perceivable beneficial quality to the cyder. Be this as it may, certain it is, that this method of converting apples to pommage by the trough and ſtone has, in the laſt fifty years, much given way to the apple-mill.

The author of the treatiſe on the apple and the pear has remarked that when iron mills have been tried, this metal has been found to be ſoluble in the acid of apples, to which it communicates a brown colour and an unpleaſant taſte. No combination has, he believes, been aſcertained to take place between this acid and lead; but as the oxyd or calx of this metal readily diſſolves in, and communicates an extremely poiſonous quality to, the acetous juice of the apple, it ſhould, he thinks, never be ſuffered to come into contact with the fruit or liquor. In the conſtruction of theſe mills, there are various methods had recourſe to in regard to their motion or moving powers, ſome being worked by hand, ſome by horſes, and others by water. The horſe and water powers have obviouſly conſiderably the advantage in the quantity of work that is capable of being performed; but the hand method is ſuppoſed capable of reducing the pulp into a ſtate of greater fineneſs, where the lateſt improvements in mills of this kind have been adopted. See CYDER-*Mill*.

It has been ſuggeſted in the Herefordſhire report, that each ſort of apples ſhould be ground ſeparately, or at leaſt ſuch ſorts in mixture as become ripe at the ſame time; but on the authority of Mr. Appeſley of Withington and other manufacturers, it is ſtated, that the former practice is that by which "fine cyder of different flavours and degrees of ſtrength is obtained, from the ſame orchard, the liquors being mixed after they are made." It is however allowed that "in all common caſes," the practice of grinding different varieties of fruit equally ripe, together, is found eligible; as it is leſs difficult to find the requiſite degrees of richneſs, aſtringency, and flavour, in three varieties, than in one. And hence it is ſuppoſed that cyders made from the juice of mixed fruits under common management, generally ſucceed with greater certainty, than thoſe from only one kind. In the grinding, the fruit ſhould be reduced as nearly as poſſible to an uniform conſiſtence, in ſuch a manner as that the rinds and kernels may be ſcarcely diſcernible from the general maſs; the operation proceeding ſlowly, with a free acceſs of air. The quantity of fruit which is uſually thrown into the ciſtern at one time to be ground, is about two buſhels in the large mills.

Preſſing the ground fruit.—It is remarked by Mr. Crocker, that cyderiſts are not agreed in opinion, whether the pommage ſhould immediately after grinding be conveyed to the preſs, there to be formed into a kind of cake, or what is ſometimes called the cheeſe; or whether it ſhould remain ſome time in that ſtate before preſſing. Some ſay it ſhould be preſſed immediately after grinding; others conceive it beſt to ſuffer it to remain in the grinding trough, or in vats employed for the purpoſe, for twenty-four hours, or even two days, that it may acquire not only a redneſs of colour, but alſo that it may form an extract with the rind and kernels. Both extremes are, he thinks, wrong. There is an analogy, he ſuppoſes, between the making of cyder from apples, and wine from grapes; and the method which the wine-maker purſues ought, he thinks, to be followed by the cyder-maker. When the pulp of the grape has lain ſome time in the vats, the vintager thruſts his hand into it and takes ſome from the middle of the maſs; and when he perceives by the ſmell that the luſcious ſweetneſs is gone off, and that his noſe is affected with a ſlight piquancy, he immediately carries it to the preſs, and by a light preſſure expreſſes his prime juice. In like manner ſhould the cyderiſt determine the time when his pulp ſhould be carried to the preſs. If he carry it immediately from the mill to the preſs, he might loſe ſome ſmall advantage, which may be expected from the rind and kernels, and his liquor may be of lower colour than he might wiſh. If he ſuffer it to remain too long unpreſſed, he will find to his coſt, that the acetous fermentation will come on before the vinous is perfected; eſpecially in the early part of the cyder-making ſeaſons. He will generally find, he thinks, that his pulp is in a fit ſtate for preſſing in about twelve or ſixteen hours. If

he muſt, of neceſſity, keep it in that ſtate longer, he will find a ſenſible heat therein, which will engender a premature fermentation; and he muſt not delay turning it over, thereby to expoſe the middle of the maſs to the influence of the atmoſphere. Mr. Knight, however, thinks it ſhould remain twenty-four hours before it is taken to the preſs. And the writer of the "General view of the ſtate of agriculture in the county of Glouceſter," ſtates that there the pulp is either immediately carried to the preſs, or, which is better, laid up in tubs or open caſks for twenty-four hours; by which the colour is improved, and by the digeſtion which takes place, a more intimate union of the rind, kernel, and ſtalk juices are produced, eſpecially when again carried to the mill and reground. See Cyder-*Preſs*.

The ground fruit or pommage being now in a proper ſtate, it is carried to the preſs, and a ſquare cake or cheeſe made of it, by placing very clean ſweet ſtraw or reed between the various layers of pulp or pommage; or by putting the ſame into hair-cloths ſpread upon the vat, and placing them one on another. They are turned up on the ſides and corners over the pulp, ſo as to nearly meet in the centres. They are laid very even, ten or twelve being often applied over each other in regular layers, the ſquare frame of the preſs being raiſed with them, keeping the pile to an uniform ſize. Upon the whole, a ſtrong board is placed, wider than the pile, on which the blocks of the preſs reſt. It is of importance that the ſtraw or reed, where they are uſed, be ſweet and perfectly free from any fuſtineſs, leſt the cyder be impregnated therewith. Particular care ought alſo to be taken to keep the hair-cloths ſweet, by frequently waſhing and drying; or the ill effects of their acidity will be communicated to the cyder. To this cake or cheeſe, after ſtanding a while, a ſlight preſſure is at firſt to be given by lowering the ſcrew of the preſs, which muſt be gradually increaſed as the cakes become dryer, until all the muſt or juice is expreſſed, which is uſually completed by the long lever and windlaſs: after which, the juice muſt be ſtrained through a coarſe hair ſieve, to keep back the groſs feculencies of the juice, and be put into proper veſſels. Theſe veſſels may be either open vats, or cloſe caſks; but as in the time of a plentiful crop of apples, a number of open vats may by the cyderiſt be conſidered an incumbrance in his cyder-rooms, the muſt ſhould be generally carried immediately from the preſs to the caſk. The preſſed pulp or cheeſes, as they are termed, on being removed from the preſs and taken out of the cloths, are thrown away, when not deſigned for further uſe; but when the crops are ſcanty they are ſometimes laid by in ſome places, to be afterwards reground with water, from which is afforded a liquor of weak quality, which is denominated in ſome places *waſhings*, but of ſufficient ſtrength to render it fit for family uſe; as notwithſtanding the utmoſt attention in grinding, and the greateſt exertion of the preſs, ſome portions of the fruit remain unbruiſed, which contain juice in an unexpreſſed ſtate. It is found that the reſidue of a quantity of fruit, ſufficient for making three hogſheads of cyder, is capable of yielding about one hogſhead of waſhings.'

Fermenting, racking, and caſking the liquor.—Theſe are the next operations to be regarded in the manufacture of this liquor. It is ſuggeſted by Mr. Crocker, that cyder making is thus far a mere manual operation, performed with very little ſkill in the operator; but that now it is that the great art of making good cyder commences: nature ſoon begins to work a wonderful change in this foul-looking, turbid, fulſome, and unwholeſome fluid; and, by the proceſs of fermentation alone, converts it into a wholeſome, vinous, ſalubrious, heart-cheering beverage. He thinks that philoſophy has ſhown, and that experience juſtifies the poſition, that the juices of all vegetables, when expoſed to certain degrees of heat and atmoſpheric influence, are diſpoſed by nature to ſpontaneous inteſtine motions of their conſtituent parts: this is called fermentation.

And it is obſerved by Mr. Knight, that the juice of the apple in its unfermented ſtate conſiſts of ſugar, vegetable mucilage, acid, water, its tinging matter, the principle of ſmell, and, he believes, of aſtringency. Of theſe component parts, the firſt only is known to be capable of producing ardent ſpirit, and it might thence be inferred that the ſtrongeſt cyders would be afforded by the ſweeteſt fruits: but the juice of theſe generally remains defective in what is termed "body" in liquors, and it is extremely apt to paſs from the ſaccharine to the acetous ſtate. Much of the ſtrength of cyder is ſuppoſed by the Herefordſhire farmers to be derived from the rind and kernels of the fruit, and hence ariſes their great attention to grind it thoroughly; the ſtalks alſo are neceſſarily reduced, when the apples are thoroughly ground, and he ſuſpects that the body of the liquor is ſtrengthened, and its flavour improved by the aſtringent juice of theſe: yet it does not appear probable, he ſays, that either of them contains any ſaccharine matter.

It is further ſtated as well-known that there are various ſtages of fermentation in the juices of all vegetables, each of which changes the very nature and quality of the fluid; but the principal ones which are to be particularly attended to, in the inſtance now under conſideration, (the muſt or juice of apples,) are theſe; namely, the vinous, the acetous, and the putrefactive. The firſt converts the muſt from its turbid, fulſome ſtate, to a tranſparent ſpirituous liquor, lightly piquant on the palate, reſembling wine both in its flavour and effects.

The above writer ſtates in addition, that it has been obſerved to take place in ſuch bodies only as contain a conſiderable portion of ſugar, and that it is always attended with the decompoſition of that ſubſtance. The liquor gradually loſes its ſweetneſs, acquiring an intoxicating quality, and by diſtillation affords a greater or leſs quantity of ardent ſpirit, according to the quantity of ſugar it originally contained, and the ſkill with which the proceſs has been conducted. When this fermentation proceeds with too much rapidity, it is often confounded with the acetous, but the products of that are totally different. A violent degree of fermentation however, though purely vinous, is extremely injurious to the ſtrength and permanence of cyder, probably owing to a part of the ardent ſpirit being diſcharged along with the diſengaged air or gas.

'If," ſays the author of the Tract on Cyder-making, "the juice has been expreſſed from ſour apples, this fermentation is perfected in two or three days; but if from ſweet apples, not under a week or ten days, and ſometimes longer."

The next ſucceeding ſtage of fermentation gives an acidity to the vinous liquor before ſpoken of, converting it to a ſort of vinegar. This fermentation begins ſoon (frequently in a few hours) after the vinous is ended, and if the fermentation be improperly haſtened by heat, before the vinous can be perfected. And Mr. Knight has remarked that it uſually ſucceeds the vinous; but that it will ſometimes precede it, when the liquor is in ſmall quantity and expoſes a large ſurface to the air. In this proceſs, vital air is abſorbed from the atmoſphere, and the ardent ſpirits, vegetable acid, and ſugar, if any remain, are alike converted into vinegar.

It is alſo further remarked that in the putrefactive proceſs which follows the acetous, the vinegar loſes its acidity,

becomes foul and viscid, and emits air of an offensive smell: an earthy sediment subsides, and the remaining liquid is little but water. But although we cannot, Mr. Crocker thinks, form any clear and distinct knowledge of the precise manner in which nature performs these changes in fermenting liquors, yet the effects are evident; and from a consideration of the different natures and results of the various fermentations, it may be perceived, that the first is the only one useful in making good cyder, and that the others tend to vitiate, and render unwholesome a liquor that would otherwise be highly pleasant, and truly salubrious. To regulate the first and to check the others, is then, says he, the greatest business of that cyder-maker, who would attach to himself the satisfaction and fame which every one is emulous of acquiring and deserving.

In the view of attaining these ends, fermentations should not, he thinks, by too much heat, be carried on rapidly, nor by extreme cold, too slowly; as, in each case, the fermenting body must be injured. Hence (he says) it appears, that a certain degree of warmth, or rather imperceptible heat, conduces best to regulate this operation. This degree of warmth may be understood to rest between forty and fifty degrees of Fahrenheit's thermometer. If then the warmth of the cellar, in which new-made cyder is placed, be between these points (no adventitious cause intervening), we may expect that the vinous fermentation will commence and go on with due regularity, and in a proper manner.

It has been observed above, that fermentation is an intestine motion of the parts of a fermentable body. This motion, in the present case, is always accompanied with an evident ebullition; the bubbles rising to the surface, and there forming a scum, or soft and spongy crust, over the whole liquor. This crust is frequently raised and broken by the air as it disengages itself from the liquor, and forces its way through it. This effect continues whilst the fermentation is brisk, but at last gradually ceases. The liquor now appears tolerably clear to the eye, and has a piquant, vinous sharpness upon the tongue. If in this state the least hissing noise be heard in the fermenting liquor, the room is too warm; and atmospheric air must be let in at the doors and at the windows.

"This (continues he) is the critical moment, which the cyderist must not lose sight of; for, if he would have a strong, generous, and pleasant liquor, all further sensible fermentation must be stopped. This is best done by racking off the pure part into open vessels, which must be placed in a more cool situation for a day two, after which it may again be barrelled, and placed in some moderately cool situation for the winter. The Herefordshire cyder-farmers, after the cyder has perfected its vinous fermentation, place their casks of cyder in open sheds throughout the winter: and, when the spring advances, give the last racking, and then cellar it. In racking, it is advisable that the stream from the racking-cock be small, and that the receiving-tub be but a small depth below the cock: lest, by exciting a violent motion of the parts of the liquor, another fermentation be brought up.

Though in common practice the racking of the liquor is rarely much attended to, especially for some months after casking, this being the old method; there cannot, however, be much doubt but that it should be accomplished at the proper moment as shewn above; in proof of which it is found that in the management of the finer liquors, in some districts, in which the fermentation is rapid, some have servants in constant attendance to watch its progress, racking it when necessary, even in the night, as such saccharine liquors require timely checking to prevent their taking on the acetous state.

But though frequent rackings have, without doubt, a tendency to reduce the liquor to a quiet state, the strength is supposed to be considerably lowered by it, in consequence of the continual escape of the spirit by exposure to the atmosphere. Brandy, or any other clean spirit may likewise be employed for the same purpose as racking, if not found too dear. The same object may also be obtained in some measure by leaving the cask unfilled, with an ullage. Where the tendency to fermentation is great, the casks should not be too much filled to the bung-hole, the action of the air on the surface of the liquor being favourable to the checking of that process.

The grounds, lees, or feculence of the cyder, after racking, may be strained through filtering bags, made for the purpose, of coarse linen or hempen cloth, and the running placed among the second-rate cyders; but by no means should it, in Mr. Crocker's opinion, be returned to the prime cyder. Some find it useful in checking any farther irregular fermentation in the casks. In this situation the cyder will, in course of time, by a sort of insensible fermentation, (the same writer says) not only drop the remainder of its gross lees, but will become transparent, highly vinous and fragrant.

"But, (it is observed by Mr. Knight,) that after the fermentation has ceased, and the liquor is become clear and bright, it should instantly be drawn off, and not suffered on any account again to mingle with its lees; for these possess much the same properties as yeast, and would inevitably bring on a second fermentation. The best criterion to judge of the proper moment to rack off will be (he says) the brightness of the liquor; and this is always attended with external marks, which serve as guides to the cyder-maker. The discharge of fixed air, which always attends the progress of fermentation, has entirely ceased; and a thick crust, formed of fragments of the reduced pulp, raised by the buoyant air it contains, is collected on the surface. The clear liquor being drawn off into another cask, the lees are put, he says, into small bags, similar to those used for jellies, being made, as noticed above: through these, whatever liquor the lees contain gradually filtrates, becoming perfectly bright, and it is then returned to that in the cask, in which it has the effect, in some measure, of preventing a second fermentation, as already hinted. It appears, he says, to have undergone a considerable change in the process of filtration. The colour is remarkably deep, its taste harsh and flat, and it has a strong tendency to become acetous; probably by having given out fixed, and absorbed vital air. Should it become acetous, which it will frequently do in forty-eight hours, it must not, on any account, he says, be put into the cask. If, however, the cyder, after being racked off, remains bright and quiet, nothing more is to be done to it till the succeeding spring; but if a scum collects on the surface, it must immediately be racked off into another cask; as this would produce bad effects, if suffered to sink. If a disposition to ferment with violence again appears, it will be necessary, he thinks, to rack off from one cask to another, as often as a hissing noise is heard. The strength of cyder is much reduced, he says, as noticed above, by being frequently racked off; but this, he supposes, arises only from a large portion of sugar remaining unchanged, which adds to the sweetness, at the expence of the other quality. The juice of the fruits which produce very strong cyders, often remains muddy during the whole winter, and much attention must frequently be paid, to prevent an excess of fermentation.

The casks into which the liquor is put, whenever racked off, should always have been thoroughly scalded, and dried again; and each should want several gallons of being full, to expose a larger surface to the air of the atmosphere.

But, says he, should the cyder-maker neglect the above precautions, the inevitable consequence will be this: another fermentation will quickly succeed, and convert the fine vinous liquor he was possessed of into a sort of vinegar; and all the art he is master of will never restore it to its former richness and purity.

When, however, the acetous fermentation has been suffered to come on, the following attempts may, he says, be made to prevent the ill effects of it from running to their full extent. For this purpose several means have been tried, sometimes with a degree of success, at other times wholly unavailably; the most popular ones would, however, seem to be these: as already noticed, a bottle of French brandy, half a gallon of spirit extracted from the lees of cyder, or a pailfull of old cyder, poured into the hogshead soon after the acetous fermentation is begun: but no wonder, continues he, if all these should fail, if the cyder be still continued in a close warm cellar. To give effect to either, it is necessary that the liquor be as much exposed to a cooler air as conveniently may be, and that for a considerable length of time. By such means it is possible fermentation may, in a great measure, be repressed; and if a cask of prime cyder cannot from thence be obtained, a cask of tolerable second-rate kind may. These remedies are innocent; but if the farmer or cyder-merchant attempt to cover the accident, occasioned by negligence or inattention, by applying any preparation of lead, let him reflect that he is about to commit an absolute and unqualified murder on those whose lot it may be to drink his poisonous draught. Such means should, therefore, on no account be ever had recourse to.

The practice which is provincially termed *stumming*, and which signifies the fuming a cask with burning sulphur, may sometimes be advantageous. It is thus performed: take a stripe of canvas cloth, about twelve inches long and two broad; let it be dipped into melted brimstone: when this match is dry, let it be lighted, and suspended from the bung of a cask (in which there are a few gallons of cyder) until it be burnt out. The cask must remain stopped for an hour or more, and then rolled to and fro, to incorporate the fumes of the match with the cyder; after which it may be filled. If the *stumming* be designed only to suppress some slight improper fermentation, the brimstone match is sufficient; but if it be required to give any additional flavour to the cyder, some powdered ginger, cloves, or cinnamon, &c. may be strewed on the match when it is made. The burning of these ingredients with the sulphur will convey somewhat of their fragrance to the whole cask of cyder; but to do it to the best advantage, it must be performed as soon as the vinous fermentation is fully perfected.

It is stated by Mr. Crocker, that when the cyderist has succeeded in obtaining a favourable vinous fermentation, and by a well-timed racking and attention he has prevented the acetous and other succeeding fermentations from rising, his cyder will require very little further attention, more than filling up the vessels every two or three weeks, to supply the waste by the insensible fermentation, until the beginning of the succeeding March; at which time it may be reasonably expected he will find his cyder bright, pure, and in a fit state for its final racking. This should be done in fair weather; and, if necessary, a commixture should now be made of the high-coloured cyder, made from the Jersey, or the luscious sweet apples, with that of the pale-coloured cyder from the poorer sour apples: by which means a general regular colouring may be obtained with the least trouble, and without expence in any way.

Though it may be expected that the cyderist will now find his liquor to his mind, both in point of brightness and colour, yet should he be disappointed, this is the time for applying some innocent remedy to remove the disorder. He does not recommend to him either of the *forces* commonly used for fining liquors, namely, bullock's blood, isinglass, eggs, &c. as they as frequently spoil a cask of cyder as improve it; but if he put two pounds of lump sugar into a hogshead of cyder, he will receive all the benefit which may be expected from the most nauseous *force* which nastiness can employ. If higher colour in cyder be desired than what his fruit naturally gives under the foregoing management, the cyderist will do well, he says, to melt a pound of lump-sugar in a stewpan, over a clear fire, stirring it frequently, until it comes to a very dark brown colour; then to take it off the fire, and, as it cools, add some cyder thereto by little and little, and continue stirring it until it becomes a thin uniform fluid. This colouring, in the quantity of about a pint, more or less as occasion may require, to a hogshead, is very cheap and wholesome, tinges to perfection, gives no luscious sweetness, but rather an agreeable bitterness, and thus recommends itself to the nicer palates. Soon after this spring racking, but not till then, the casks may be gradually stopped, by first laying the cork on the bung-hole, and in a few days forcing it very tightly into it, covering it over with a layer of melted rosin, or other similar substance.

Bottling the Liquor.—This is the next business to be attended to in the management of cyder; and it is stated by the writer just mentioned, that in the month following, that which is named above, the cyder, in general, will be in a fit state for this operation; but that the critical time for this process is when the liquor has acquired in the cask its highest degree of perfection: then, when the weather is fair, the barometer high, and the wind in some northerly point, let the bottles be filled, setting them by uncorked, until the morning; then let the corks be driven very tightly into the necks of the bottles, tied down with small strong twine or wire, and well secured with melted rosin, or other material of the same nature.

It is stated by Mr. Knight, that cyders which have been made from good fruits, and have been properly manufactured, will retain a considerable portion of sweetness, in the cask, to the end of three or four years; but that the saccharine part, on which alone their sweetness depends, gradually disappears, probably by a decomposition and discharge of fixed air, similar to that which takes place in the earlier stages of their fermentation. Cyder is generally in the best state to be put into the bottle at two years old, where it will soon become brisk and sparkling; and if it possesses much richness, it will remain with scarcely any sensible change during twenty or thirty years, or as long as the cork duly performs its office, or resists decay.

But in making cyder for the common use of the farm-house, the same writer says, few of the foregoing rules are or ought to be attended to. The flavour of the liquor is here a secondary consideration with the farmer, whose first object must be to obtain a large quantity at a small expence. The common practice of the country is sufficiently well calculated to answer this purpose; the apples are usually gathered and ground as soon as they become moderately ripe; and the juice is either racked off at once, as soon as it becomes bright, or more frequently conveyed

from the preſs immediately to the cellar. A violent fermentation ſoon commences, and continues until nearly the whole of the ſaccharine part is decompoſed. The caſks are filled up and ſtopped early in the ſucceeding ſpring, and no further attention is either paid or required. The liquor thus prepared may be kept from two to five or ſix years in the caſk, according to its ſtrength. It is generally harſh and rough, but rarely acetous; and in this ſtate, the writer believes, it is uſually ſuppoſed to be preferred by the farmers and peaſantry. When it has become extremely thin and harſh by exceſs of fermentation, the addition of a ſmall quantity of bruiſed wheat, or ſlices of toaſted bread, or any other farinaceous ſubſtance, will, he ſays, much diminiſh its diſpoſition to become ſour. But the above opinion is not, he thinks, well founded; they like it beſt when it poſſeſſes much ſtrength with moderate richneſs, and when it is without any thing harſh or ſour in its flavour; but they will drink it, and to a moſt extraordinary exceſs, even when it is really in the acetous ſtate.

And, as has been ſeen above, an inferior kind of liquor is made, the writer ſays, by macerating the reduced pulp, from which the cyder has been preſſed, in a ſmall quantity of water, and regrinding it. This may be kept till the next autumn, and uſually ſupplies the place of cyder in the farm-houſe for all purpoſes, except for the labourers in the harveſt. It is generally fit to drink very ſoon after it is made; and though no attention is ever paid to it during its fermentation, it often remains, till near the end of the ſucceeding ſummer, more palatable than the cyder preſſed from the ſame fruit, which is a fortunate circumſtance for the farmer.

In the buſineſs of making perry, which is a liquor of a ſomewhat ſimilar nature, there is but little which is materially different in the proceſs. See Perry.

Produce and application of Cyder.—The produce of this liquor is a matter which is extremely difficult to aſcertain, whether the quantity be taken by the acre, or in any other way. It has been ſtated by the author of the "Preſent State of Huſbandry," in this country, that the quantity of cyder and perry made for ſale in the fruit diſtricts is very great; but that, that uſed by the inhabitants is by various accounts much more conſiderable. Theſe liquors are, he ſays, ſold by the farmers in different ſtates of preparation for market. Sometimes they are ſold immediately from the preſs, ſometimes after the firſt racking, and frequently, not until ready for uſe. The price of cyder and perry always advances according as theſe liquors are in a prepared ſtate for the conſumer's uſe, as well as according to the quantity on hand, and the quality of the fruit whence it was made. Stire cyder and ſquaſh-pear perry, for inſtance, ſays he, always give much higher prices than what is made from any other ſorts of fruit. The price of common cyder liquor from the preſs, for a courſe of ſeven years, may, he thinks, be rated at from 15*s.* to 30*s.* the hogſhead of 110 gallons; and common perry from 12*s.* to 15*s.* Stire-cyder, in the ſame ſtate, ſells for 5*l.*, 10*l.*, and ſometimes 15*l.* the hogſhead; and ſquaſh perry, in ordinary ſeaſons, from 4*l.* to 8*l.* the hogſhead.

But the produce of cyder or perry by the acre can only, he ſays, be gueſſed at by firſt aſcertaining the number of trees. From an orchard of trees, in full bearing, half a hogſhead of cyder may, in ſeaſons ordinarily favourable, he thinks, be expected from the fruit of each tree. As the number of trees on the acre varies from ten to forty, the quantity of cyder muſt vary in the ſame proportion; that is, from five to twenty hogſheads. Pear trees, in equally good bearing, yield fully one-third more liquor; therefore, although the liquor extracted from pears ſells at a lower price than that produced from apples, yet the value by the acre, when the number of trees is the ſame, is nearly on a par.

Mr. Vancouver, in his Survey of the County of Devonſhire, has remarked, that the great uncertainty of this ſort of crops renders it a matter of great difficulty, to ſtate any thing like an average produce of that diſtrict. He has found, however, that the mean, of ſeveral ſtatements taken upon a period of ſeven years, which varied from two and a half to five hogſheads per acre, will be found to equal that of three hogſheads and two-fifths for the acre. And that the average price of the liquor at the *pound's* mouth, or preſs, was, in 1807, fifty ſhillings the hogſhead.

And the intelligent writer of the Report of the County of Glouceſter, has offered a ſtatement of the expence, produce, and profit of this kind of crop, in a different way on the extent of twenty acres.

Suppoſing the diſtance of planting the trees to be ſixteen yards, the acre will admit ſixteen ſtocks, which, with the original coſt, planting, and fencing, may be eſtimated at 5*s.* each, or in the whole 4*l.*

Grafting, protecting, and keeping up fences till the trees are out of danger, may be ſtated at 2*s.* 6*d.* each.

It is ſuggeſted, that the return to the landlord will be very ſmall for the firſt twenty years; and that he will not be able to put an additional rent on his lands, in leſs than thirty years, for the plantation.

The coſt of erecting a cyder-houſe and mill ſtated at eighty pounds.

General Eſtimate.	£.	*s.*	*d.*
Planting 20 acres - -	80	0	0
Grafting, protecting, repairing, &c.	40	0	0
Intereſt for 30 years on 80*l.* -	120		
Building cyder-houſe, &c. -	80		
Total expence	320	0	0

	£.	*d.*
Intereſt of 320*l.* -	16	0
Profit - -	14	0
	30 0 0	
Advance of rent on 20 acres	30 0 0	

Conſequently the landholder has the diſtant proſpect, he ſays, of increaſing his income 14*l.* per annum, or of receiving nearly 10 *per cent.* for money laid out, but ſubject to the deductions of repairs, &c.

But that, with the tenant the advantages are ſtill leſs certain. Suppoſe the ground to be ſo well planted and grown as to contain ſixteen trees capable of affording in a good ſeaſon ſixteen barrels, or 800 gallons of cyder, which is a large average allowance; and ſuppoſe the liquor to be ſold from the mill at 4*d.* the gallon, the produce will be 13*l.* 6*s.* 8*d.* per acre, ſubject to the deductions of 20*s.* for tythes, 2*l.* for making, 10*s.* for gathering; in the whole 3*l.* 10*s.*: the remainder, 9*l.* 16*s.* 8*d.* will be clear profit; which, if it occurred every year, it would be conſidered highly beneficial; but a good crop rarely happens oftener than once in four years, while the damage done to the graſs under the trees is continued, as well as the increaſed parochial rates from the increaſed rent; it does not ſeem, therefore, the writer ſays, that the additional rent on account of the trees, is returned with much intereſt.

Though there are many individuals in the cyder diſtricts who evince much care and attention in the management of

their orchard-grounds, trees, fruit, liquor, &c.: Yet this is by no means, he fays, the common cafe; on the contrary, fuch general negligence prevails, and fo imperfect are the modes in which this branch of hufbandry is for the moft part conducted, that many are of opinion, fo much valuable land being occupied as orchards, is, in a national view, extremely unprofitable; and that owing to the fame caufes, want of attention, and adopting improper modes of management, the farmers at large are alfo injured, rather than benefited. While, fays he, orchards continue to be confidered as fecondary objects only of the farmer's attention, as is the cafe at prefent, it can hardly be expected that the produce will be abundant, or the quality fuch as to recommend it to more general notice. In place, however, of condemning orchard hufbandry at large, it appears much more correct, he thinks, to recommend a general reform in the management; whereby liquors, that are both wholefome and agreeable, when well made, may be introduced into more general ufe, and fo large an importation of foreign vinous liquors be rendered unneceffary. In place of planting only ten or a dozen of trees on the acre over an extenfive tract of land, it would, he fuppofes, be more for the intereft, and certainly much more convenient for the cyder-men, were they to allot a few acres adjoining to their places of refidence, for the fole purpofe of growing fruit-trees. The lofs and inconvenience of having fruit trees fcattered over an arable field, are confiderable. When the trees are full grown, they overfhadow, and confequently greatly injure the crop below; the roots alfo fpread to a great diftance, and befides impeding the ploughing of the ground, extract a great fhare of the nourifhment that would otherwife go to fupport the crop of corn. The additional expence in gathering and carrying home a crop of fruit from an extenfive fruit-ground, beyond what is incurred when four trees ftand on the fame fpace of ground which in the other cafe is occupied by one, alfo merits attention. Inconveniences as great and numerous refult from having fruit-trees thinly fcattered over a pafture field. The grafs under the fhadow of the trees is very inferior to that in the open part of the field. The cattle muft, fays he, be excluded when the fruit-trees begin to ripen, efpecially during and immediately after high winds, otherwife they would eat the fruit. The falling of leaves in autumn is very deftructive to paftures of all defcriptions; and the fame additional expence and trouble of gathering and carrying home the crop are alfo incurred. For thefe reafons, a clofe planted cyder-orchard muft, he thinks, be preferable to fields; and where the foil and fituation are proper, the grounds ftocked with full-bearing trees of the beft forts; and when the trees, the fruit, and the liquor, are judicioufly managed, it is impoffible but, according to the produce and prices above-ftated, fuch grounds muft turn out profitable, even fuppofing they produce but one crop equal to that above-mentioned, every third year. On the other hand, if the flovenly manner of conducting the various operations of cyder-making be perfifted in, it would be in favour of the nation, and of the individuals concerned in that branch of hufbandry, he fuppofes, that there were not a cyder-orchard in the ifland. Perhaps, on another account alfo, it might be for the intereft of the farmers in the fruit diftricts that orchards were abolifhed: the quantity of cyder annually ufed by the fervants and labourers is fo immenfe, that confidering the injury which the crops of grain and grafs fuftain from the land's being incumbered with trees, the labour of collecting and carting home the fruit, and the trouble attending the manufacturing it into liquors, this beverage muft be a more ferious article of expence than the generality of cyder farmers are difpofed to allow.

It is, however, ftated by Mr. Rudge, that where the management of thefe forts of liquors is perfectly known and attended to, and there is a capital fufficient to prevent the neceffity of immediate fale, as well as plenty of cafks in the farmer's own cellar, he may be enabled to take the advantage of the moft favourable circumftances of bringing it to the market, as when there is a fcarcity from early fales, and no fupplies expected from crops of fucceeding years; when the price is frequently increafed to 8*d.* or 1*s.* the gallon.

It is added, that old cyder is always valuable, and pays for keeping; which is fuggefted as the beft means of countervailing the uncertainty of crops, though it oftener benefits the dealer than the grower of the fruit.

The fame able writer alfo ftates, that farmers who live contiguous to canals or navigable rivers, have peculiar advantages from their fituations, often turning long keeping fruits to a better account than grinding them for cyder, by fending them into the interior diftricts of the kingdom for the purpofe of the table, at the price of 16*s.* per feam: "for," fays he, "fuppofing that eleven feams of nine pecks each, are required for 100 gallons, the cyder fhould be fold at 8*l.* 16*s.* to equalize the profit of their fale unground; but cyder, in its early ftate, feldom averages more than 9*d.* per gallon, which would be only 3*l.* 15*s.*; fo that even fuppofing all the cyder to turn out well, the former method is far the more advantageous. It is therefore conceived, that in this way alone, the profits of a fruit eftate can be fatisfactorily made out in favour of the tenant of it. See Orchard, and Apple-*tree*.

Cyder-*Cafk*, in *Rural Economy*, a veffel of the barrel kind, made ufe of for the purpofe of keeping the liquor. They are of various fizes or dimenfions, according to the extent of the fruit grounds, and the fancy and circumftances of the farmer, in fo far as capital is concerned. It is, however, commonly fuppofed that the ftrength of the liquor is better preferved, if not increafed, by a large quantity or body of it being kept together. Though cafks of this fort are made to hold from 400 to 500 gallons, the moft general fize is 110 gallons, which is alone employed in fending out the cyder for fale. The ufual price of this kind of cafks is about five-pence the gallon.

It is obferved that the choice of proper veffels for keeping the liquor in after it has been fermented, is a very material point to be regarded, as none is fo liable as this to take the tafte or twang of the cafk: new veffels, though the wood be ever fo well feafoned, are apt to give a difagreeable relifh to all liquors, and remarkably fo to cyder, unlefs due caution be ufed beforehand. Frequent fcalding with hot water, into which fome handfuls of falt have been firft thrown, or with water in which fome of the pommage has been boiled, and wafhing afterwards with cyder, are the ufual remedies againft this evil, and feldom fail of removing it effectually. Of all forts of old cafks, beer veffels are the worft, as they always fpoil cyder; and in return cyder cafks infallibly fpoil beer. Wine and brandy cafks do very well, provided the tartar adhering to their fides be carefully fcraped off, and they are well fcalded. Thefe different circumftances fhould always be carefully attended to, in cleaning and preparing cafks of this kind for the reception of the liquor.

Cyder-*Cloths*, are fuch cloths as are manufactured for the purpofe of the cyder-maker, being made ufe of for

containing the pommage, in order to its undergoing the operation of the prefs. They are ufually formed of common hair-cloth, but which is of the more clofe and compact nature or texture.

The fize is generally about four feet fquare; and they hold about two or three bufhels, or as much as the mill can grind at once; and thefe are, as has been feen, heaped over each other until the prefs is full, being kept to an uniform fize by a wooden frame or gauge. The larger preffes are capable of holding from eight to fifteen bags or cloths, which yield from one to two hundred gallons of liquor, according to the largenefs of what is termed the *cheefe*. To perform the work neatly, it is neceffary to have two fets of thefe cloths or bags, as they are apt to clog and fur in preffing, and confequently become unfit for ufe again till they have been wafhed and dried; fo that while this is doing, either the prefs muft ftand ftill, or another fet be ready to employ it. But fome, inftead of cloths or hair-bags, lay dry ftraw under the pommage, the ends of which they turn up over it; then cover the pommage entirely with frefh clean fweet-fmelling ftraw, upon which they fpread another layer of pommage; and fo on alternately, until the prefs is full. Either of the methods will anfwer the purpofe: but thofe who are defirous of doing the work in the neateft and beft manner, generally ufe hair bags or cloths in performing the bufinefs. See CYDER.

CYDER-*Kin*, an inferior fort of fruit liquor, which is made after the better kind has been prepared, in the manner which has been noticed in fpeaking of cyder. (See CYDER.) It is moftly ufed for domeftic purpofes.

CYDER-*Mill* is that fort of machine or contrivance, which is conftructed for the purpofe of crufhing, grinding, and reducing apples, or other fimilar fruits, into the ftate of a fine pulp or pommage, in order that the juice or liquor may be drawn from it, by means of preffure. In different diftricts there are variations in the manner of conftructing thefe mills; but they chiefly confift of two kinds, the horfe and the hand mills; the former being principally in ufe where the extent of fruit ground is confiderable, but the latter moftly where the farms of this kind are fmall, and infufficient to repay the expence of fuch large machinery.

The firft fort, or *horfe-mill*, which is that by much the moft generally met with, is commonly conftructed fomewhat on the fame principles as thofe in ufe for the purpofe of grinding bark for the tanners; and confifts of the following diftinct parts, namely, the ciftern-chafe, or trough, the runner or bruifing-ftone, and the cog-wheel and upright axle-tree, with the ftirrer, the reever, and the fhovel employed in the procefs.

It is ftated by Mr. Rudge, in his "Agricultural Survey of Gloucefterfhire," that the ciftern is circular, and formed of ftone, being hollowed out in fuch a manner as to fit and receive the runner, commonly to the depth of about nine inches. On the inner fide, or that which is next, what is ufually termed the "nut" or central fpace, it is cut out in a perpendicular form, but on the exterior or outfide fomewhat in a floping direction, being left wider acrofs at the top than at the bottom; and the outfide upper edge is left two or three inches in width, in order to receive what is denominated a "curbing," which is made of wood, and raifes it four inches higher, being finifhed with nearly a fharp edge. The defign of this wood-work is not merely to prevent the pulp or pommage from being carried over, as the ftone rolls or turns round, but likewife to correfpond with a four-inch plank or planks, which cover the nut, or circular vacant fpace in the centre. It is ufual for the ciftern to be delivered from the quarries in three or four feparate parts, which are afterwards fitted and cramped together by the mill-wright. A ciftern of thirty feet in circumference will be requifite for a mill of the ordinary fize; and the price is regulated by the number of gallons which it is capable of containing, or at the rate of one guinea the foot in diameter.

In regard to the runner or bruifing ftone, it is feldom lefs than three feet and a half, or more than four feet in diameter, being made perfectly flat on the fide next the nut, but a little convex on the other, nearly fitting the bottom of the ciftern. In the middle, a ftrong axle of wood is faftened through it, which is connected with an upright or ftandard axle-tree in the centre, which extends fufficiently far from the exterior fide of the runner to connect by means of an iron rod with a wooden bar, which is alfo linked to the upright axle, and to which the horfe is faftened. This wooden bar or pole is fo fixed as to be before the runner, and keep the horfe clear of it. The height is regulated by a fubftructure of ftone work under the ciftern or chafe.

To the horizontal axle is fitted a cog-wheel of from eighteen inches to two feet in diameter, which runs on the wood-work that covers the whole fpace; from the interior edge of the ciftern to the perpendicular axle, and which is denominated the nut. The exact height of this wheel muft confequently be determined by that of the centre of the runner above the nut. The cogs of this wheel catch upon upright teeth, fixed in the nut, as it rolls upon the furface, and by this means force the ftone into a rotatory motion, which under other circumftances it would not always keep; as when the apples are firft introduced, or when the bottom of the ciftern has become fmooth from the pulp, it might flide along rather than roll, was it not for fome machinery of this nature; though fome mills are without it notwithftanding.

The perpendicular axle-tree has an iron pin at each end as pivots, which runs in a funk iron centre; the wood of the axle, which is bound with an iron ring or hoop, forming the fhoulder of it.

The runner, or ftone for grinding, is commonly fold at the quarry at the rate of one guinea the foot, or as many guineas as the ftone meafures feet in diameter; being, in the diftrict mentioned above, procured from the foreft of Dean. They are a fort of dark reddifh kind of grit ftone, not calcareous, but of fufficient hardnefs.

It is fuggefted by Mr. Marfhall that much depends upon the quality of the ftone. It fhould not be calcareous, either in the whole or any part, as the acid of the liquor would, in that cafe, corrode and decompofe it. Some of the ftones in Herefordfhire have, he fays, calcareous pebbles in them, which being diffolved as above, of courfe leave holes in them. Nor fhould the ftone be of fuch a kind as to communicate a difagreeable tinge to the liquor.

The fame writer remarks likewife that there are fome mills of this kind which have two runners, one oppofite the other. And he thinks that the fituation of thefe mills fhould be fuch as to have a horfe-path, of about three feet in width, between the bed and the walls; confequently, a moderate fized mill, with its horfe-path, takes up a fpace of fourteen or fifteen feet in every direction.

At *Fig*. 1. in *Plate* XI. on *Agriculture*, an improved mill of this fort is reprefented, in which A is the runner or ftone, B C D the ciftern-chafe or trough, in which the

ſtone moves and reduces the apples; E F G the horſe-path; and H I the manner in which the moving power is attached.

The other appendages of the cyder-mill noticed above may be thus deſcribed:

The *ſtirrer* conſiſts of a ſtrong round ſtick, with which the fruit is conſtantly kept to the ſtone, and removed from the ſides to the bottom, during the proceſs of grinding; for which purpoſe, a woman or boy uſually walks either before or behind the horſe. Some horſe-mills have two ſtirrers, ſo attached to the axle-tree of the runner as to execute the work effectually without manual aſſiſtance.

The *reever* is a ſmall piece of board ſecurely faſtened to a wooden handle, and ſo formed as to fit the ſhape of the ciſtern; by means of which, when the pommage or pulp is ſufficiently ground, it is drawn together in order to be conveyed to the preſs by the ſhovel.

The *ſhovel* is a tool ſomewhat of the ſpade kind, moſtly made of wood, being a ſort of ſcoop, by which the above operation is readily performed. Iron ſhovels are, however, ſometimes made uſe of; but a portion of the iron is ſuppoſed to be diſſolved by the acid of the liquor, which may poſſibly contribute to the black tinge frequently noticed in cyder, after expoſure to the air. Wooden implements ſhould therefore, of courſe, be preferred, as being more cleanly, and, at the ſame time, free from this ſort of danger.

The ſecond ſort, or *hand cyder-mill*, is conſtituted of two toothed or indented wooden cylinders of about nine inches in diameter, each being incloſed in the manner of other mills, having a feeder at the top, and being made ſo as to be turned by the hand. By this ſort of mill, the work of bruiſing the rind, kernel, and ſtalk, as well as that of reducing the fleſhy parts to a perfect pulp, is well performed. From the circumſtance of the cylinders being ſo arranged as to be capable of being removed to a greater or leſs diſtance from each other, the buſineſs advances in a regular progreſſive manner, from the firſt cutting of the fruit until the cylinders are brought ſo cloſe together that a kernel cannot paſs without being bruiſed; and where another pair of finer toothed cylinders are had recourſe to, to work under theſe, ſo as to bring the pulp into a perfect ſtate of fineneſs, the buſineſs is ſtill more effectually executed. But though by this means much time is ſaved, more ſtrength is required in the operation. It is with difficulty that the ſame degree of fineneſs can be effected by the horſe-mill, as in ſpite of the inceſſant attention of the labourer who has the care of ſtirring the fruit while under the operation of grinding, and of keeping it to the runner, a large portion is conveyed to the preſs without having been fully reduced. A mill of this deſcription is ſhewn at *fig.* 2. in the ſame plate.

It is obſerved by the intelligent author of the Report noticed above, that "two diſadvantages attach to the hand-mill in its preſent ſtate, loſs of time and increaſe of manual labour;" it being "difficult, with the aſſiſtance of three men, to grind a hogſhead in a day;" while "with a horſe-mill, from two to three hogſheads may be made by a man and woman, or younger perſon, and one horſe;" conſequently, its ſuperiority on a large fruit farm is conceived to be decided. It is, however, added, that the hand-mill is capable of being greatly improved in the point of expedition, by the attachment of a large horizontal wheel and horſe, as has been done in ſome manufactories.

It has been remarked by the author of the Rural Economy of Glouceſterſhire, that from obſerving the great ſimplicity and high degree of perfection with which the ſugar mills grind the canes or rather preſs out their juice between two plain iron rollers, the imperfections of cyder mills appear more ſtriking. It is however noticed that the ſugar cane is a long fibrous body; and readily paſſes through between the rollers: whereas fruit being globular, and of a cellular ſubſtance, is not eaſily laid hold of, or, if caught, has no lengthened fibres to induce it to paſs, like the cane, between plain rollers. It has, however, been found, that between fluted rollers it may be made to paſs; and in conſequence, theſe rollers are in uſe, though not common. They are of caſt iron, hollow, about nine inches diameter, with flutes or teeth, about an inch wide, and nearly as much deep. In general they are worked by hand, two men working againſt each other. Between theſe the fruit paſſes twice: the rollers being firſt ſet wide, to break it into fragments, and afterwards cloſer, to reduce the fragments. But even this is not, he ſays, a perfect engine: in the reſiduum from the preſs many kernels are found. Beſides, the acid of the fruit is liable to corrode the iron, and this, in return, to tinge the liquor, though neither of theſe inconveniences is acknowledged. In a country, however, where ſtone is not eaſily to be had, this may, perhaps, be found the moſt eligible cyder-mill. But in this diſtrict, where ſtone is ſufficiently plentiful, the ſtone runner and trough ſeem to be the moſt eligible mill at preſent known: though it appears to him highly probable, that, with attention and perſeverance, a more perfect machine might be invented. Be this, ſays the writer, as it may, the preſent mill appears to be capable of improvement. It is at preſent an unfiniſhed machine: he means when it is firſt turned out of the workman's hands: time and conſtant wear do that, in part at leaſt, which the workman leaves undone. The acting parts of the machine, thoſe which are to bruiſe the rind, and cruſh the kernels, are the face of the roller and the bottom of the trough. But inſtead of their being adapted to each other, in ſuch a manner as to effect theſe purpoſes with a degree of certainty, they are left in ſuch rough unfiniſhed ſtate as in a great meaſure prevents them, during the firſt fifty years at leaſt, from performing that which is their principal intention. Inſtead of being worked over, and fitted nicely to each other, with the ſquare and chiſſel, they are hewn over with the ſtone-maſon's peck only, leaving holes and protuberances which would ſave even horſe-beans from the preſſure, much more the kernels of fruit. A runner which has been worn two and twenty years has often holes left in it which would lodge half a dozen kernels with ſafety. To account for this abſurdity ſeems, he ſays, impoſſible: perhaps the roughneſs was intended to prevent the runner from ſliding; but the uſe of the cogged wheels has ſuperſeded this intention. Perhaps it was left to gather up the fruits with greater effect; but ſurely, deep chiſſel marks, left in the form of flutes acroſs the face, would have anſwered this purpoſe better, and would perhaps have laid hold of and fixed the kernels, ſo as to ſerve their being effectually broken, preferable to any other equally ſimple expedient. Or, perhaps, the cuſtom was eſtabliſhed when the uſes of the rind and kernel were not known, and time has not yet corrected the error. He has been told, that the roughneſs is left to cut the fruit the better on its being firſt put into the trough: and that on this ingenious principle, ſome will pick their runners over as often as they wear ſmooth. To ſuch cyder-makers, he would recommend the hobnail mill, which would come much cheaper, rid work ſtill faſter, and ſave the expence of pecking. Be the origin of folly what it may, ſays he, it is painful to obſerve its effect. In this caſe, however, the folly, and, of courſe, its effect may be eaſily removed. Having made the face of the roller as true as the ſquare

and the chiffel can render it, work, fays he, the bottom of the trough to it, until not a muftard-feed can efcape them. The kernels of fruit are hard, flippery, and fingularly difficult to fix, efcaping preffure in a peculiar manner; and with fingular alertnefs.

It is remarked in addition, that another improvement of the common cyder-mill appears to be much wanted; namely, a method of preventing the materials in the laft ftage of grinding from rifing before the runner; and further, a more mechanical way of ftirring up and adjufting them in the chafe. Until thefe improvements be made, cyder-mills, fays he, muft remain, what moft of them evidently are at prefent, imperfect machines.

It has been noticed by the fame writer, that a mill-houfe, on an orchard farm, is as neceffary as a barn on thofe of other kinds. It is in general found to be one end of an out-building, or frequently an open fhed, under which ftraw or fmall implements are laid up when not in ufe. The fmalleft dimenfions poffible to render it in any degree convenient and ufeful are, he thinks, twenty-four feet by twenty; having a floor thrown over it at the height of feven feet; and a door in the middle of the front with a window oppofite; the mill being fixed up on one fide of it, and the prefs on the other; as much room as is poffible being left towards the door, in the front part, for the reception of fruit and the different neceffary utenfils.

Mr. Rudge confiders the "arrangement of the buildings for the convenience of making and ftoring fruit liquors as a matter of great importance," though it feems to have been but little attended to on old farms. The mill and prefs being often found in an infulated building at a diftance from the cellars; which occafions the employing of a man and boy, with a horfe and dray to convey the liquor to the place where it is to be cafked, which is a labour that would be unneceffary were the mill houfe and cellars attached. In fome of the more recent erections of this defcription, the fpout of the vat is fo contrived as to difcharge the liquor through an opening in the wall, into a receiver in the cellar, from which it is diftributed with facility to the different cafks which are to be filled.

The reft of the utenfils belonging to a mill-houfe are few: the fruit being fimply brought in cafks or large bafkets, and the liquor carried out in pails, or by means of fpouts as noticed above. The hair-cloths, mentioned above, are the principal addition to the mill and prefs. The expence of fitting up a cyder-mill houfe depends, Mr. Marfhall fays, on the fize and quality of the mill and prefs. One of a moderate fize, for a farm, may be furnifhed completely for from twenty to twenty-five pounds. One on a fmall fcale might be furnifhed for from ten to fifteen pounds: much depending on the diftance of carriage of the ftone. This expence is ufually borne by the landlord. A mill-houfe fubftantially fitted up will laft many years. He has obferved a mill and prefs which, by the date upon them, have been fet up more that twenty years, yet they appeared almoft as frefh as new. Many of the old mills and preffes, which are feen, may, compared with thofe, feem to be a century old; or the mills more particularly a greater age, and were probably the original mills of the farms they are upon.

Thefe obfervations fhew that confiderable attention fhould be beftowed by the fruit farmer in fitting up and completing his buildings and machinery for the management of this fort of liquor.

CYDER-*Prefs*, a machine of the prefs kind, contrived for the purpofe of forcing the juice from different forts of fruits after their fubftance has been reduced to the ftate of pulp by means of grinding. They are moftly conftructed on the fame principles as thofe of other kinds which are intended to afford a ftrong or powerful preffure, as the packing and oil-prefs.

It is conftituted, according to Mr. Rudge, of the following parts, a ciftern-ftill, vat, cheeks, or "fifters," cap and fcrew, lanthorn, bridge, prefs-blocks, fhooter, lever, windlas, and rope.

The cheeks, or fifters, are two ftrong upright pieces of oak, which are preferved in their fituations, by being let into the ground firft, and then by the ciftern-ftill, which is a thick piece of timber, extending from one cheek to the other, near to the ground, being open mortifed at each end, refting upon a fhoulder, and clipping the upright: through thefe open mortifes, and the upright, a ftrong iron pin is paffed, which prevents the cheeks from fpreading or giving way in the operation of preffing. A correfponding piece is fixed near the top, which is mortifed and faftened in the fame manner to the cheeks, through the centre of which the female fcrew or nut is made, in that cafe denominated the cap.

What is termed the vat, is a wide plank, with a groove running round it near the edge, or what is preferable, a raifed levelled border coinciding with the edge, about an inch in thicknefs, to prevent the liquor from running off at the fides, and conduct it to the fluice or fpout from which it is difcharged into the receiver. This vat is firmly fixed on the ciftern-ftill.

The fcrew, when made of wood, is moftly nine or ten inches in diameter, and which paffing through the cap, rifes three or four feet to the lower end, which is fquare; the bridge is hung, by means of a rounded pin, which is a plank reaching from one cheek to the other, being freely moveable up and down, but kept to a regular fituation or pofition by open mortifes. The lower end of the fcrew is left of a larger diameter, when the lever is intended to work in it, being in this cafe perforated and hooped with iron, but the lanthorn is more frequently fixed upon it. This is made of two circular pieces of wood, lefs than two feet in diameter, being kept eight inches apart by ten ftrong pillars, between which a piece of afh or elm timber is occafionally placed, which is termed the lever. There are two of thefe belonging to the prefs, being ufed according to the extent of power required, one being fhorter and lefs ftrong than the other, being capable of being worked by the ftrength of one man, during the commencement of the preffing; but as the liquor becomes more expreffed and when nearly exhaufted, another lever of greater length and ftrength is applied to the lanthorn, and worked by means of the windlas, which is an upright poft, turning with an iron pivot in a focket on the ground, and paffing through a beam in a rather free manner at the top, being removeable when not wanted. A rope coiled round this windlas, is hung by a loop to the end of the lever, being there fecured from fpringing off, by a wooden pin. The windlas has likewife at proper heights, from two to four bars of wood paffing through for the purpofe of handles, to which the ftrength of four men may be applied with much effect. The prefsblocks are pieces of oak, about two feet in length, and fix inches fquare, placed one above the other, croffing in alternate pairs, under the bridge, for the purpofe of keeping the lanthorn, lever, and rope above the heads of the workmen at the windlas.

It is fuggefted that iron fcrews have of late been coming much into ufe, being either caft or wrought; the price of the former being about 2*l.* 15*s.*; and of the latter nearly 10*l.* The power is fuppofed by fome to be increafed by

the finenefs of the threads in the iron fcrew, while others admit of no other fuperiority but that of durability.

The price of a good prefs with wooden fcrew is ufually about ten guineas.

It has been fuggefted by the author of the Rural Economy of Gloucefterfhire that the fituation of the prefs fhould be as near the horfe path of the mill as conveniency and the nature of the building will permit, in order to the more ready conveyance of the ground pommage or pulp from the mill to it. The fize of the cyder-prefs may be different according to the extent of the apple orchard.

An improved *Large Cyder-prefs* is fhewn at *fig.* 3, in which A A is the bafe or foundation with its fupporting parts: B, B, the cheeks or fifters: D D the crofs piece at top, through which the fcrew paffes, and which confequently contains the nut or female fcrew: E the fcrew with its appendages: F F the bridge or crofs piece which acts on the pommage: G G is the wide plank or vat on which the pulp refts in the hair bags; in which the mode of the liquor's paffing off is feen: H H (*fig.* 4.) is the windlas, with its handles, wheel, rope, &c.

At *fig.* 5, is feen a fmall *Cyder-prefs* of a different kind, which acts by means of a heavy ftone or block of wood made of a conical form, moving round the centre by a lever which is inferted into its bafe, as fhewn at A and B: C is the bed of the prefs, notched for letting off the liquor into the cafk or veffel, D, placed below: E, E, E, E, are the feet or blocks on which the whole refts.

Cyder-*fpirit*, a fpirituous liquor drawn from *cyder* by diftillation, in the fame manner as brandy from wine. The particular flavour of this fpirit is not the moft agreeable, but it may, with care, be divefted wholly of it, and rendered a perfectly pure and infipid fpirit, upon rectification. The traders in fpirituous liquors are well enough acquainted with the value of fuch a fpirit as this: they can give it the flavours of fome other kinds, and fell it under their names, or mix it in large proportion with the foreign brandy, rum, and arack, in the fale, without danger of a difcovery of the cheat.

Cyder-*Vat*, is a term applied to that part of the cyder-prefs which firft receives the liquor as it is forced out from the pulp, and by which it is conveyed into the receiver. See Cyder-*Prefs*.

It is likewife a name often given to the veffels which receive the cyder before it is racked off into the ftore cafks.

It is remarked in the Survey of the County of Gloucefter, that the vat is ftill, in fome cafes, covered with lead, although the pernicious effects of its being corroded by the acid of the liquor have been frequently experienced. It fhould on this account be always made of fome fort of hard wood.

Cylinder

Cylinder, *rolling*, in *Mechanics*, a cylinder which rolls up an inclined plane.

The phenomena of the rolling cylinder may be easily accounted for from what we have observed under centre of gravity.

For let A B E D (*Plate* XXII. *Mechanics*, *fig.* 1.) represent the section of a cylinder of wood, biassed on one side by a cylindrical piece of lead, as B, which will bring the centre of gravity out of the centre of magnitude, C, to some point, G, between C and B. Let F H be an inclined plane, whose base is F L. It is evident the cylinder laid upon the plane will no where rest but there, where a perpendicular to the horizon, F L, passes through the centre of gravity G, and that point of the plane E, in which the cylinder touches it; and this, in all angles of inclination of the plane less than that whose sine is equal to C G, the radius being C D, will be in two situations A B E D, and *a b e d*: because when the cylinder moves, the centre of gravity describing a circle round the centre of magnitude C, this circle will meet the perpendicular in two points G and *g*, in each of which the centre of gravity being supposed, the cylinder will rest. Therefore the cylinder moves from E to *e* by the descent of the centre of gravity from G to *g*, in the arc of the cycloid *G b g*.

If the cylinder A B E D, *fig.* 2. insisting on the horizontal line E L, in the point E, has the centre of gravity G in the horizontal diameter D B, it will gravitate in the perpendicular G *e*: if therefore the plane F H touch the cylinder in the point *e*, it is evident the cylinder cannot either ascend or descend on such a plane. Because G in any situation between *e* and H, or *e* and F, will gravitate to the left or right from the point in which the cylinder touches the plane; and so will in either case bring it back to the point *e*. And as the angle E C *e* is equal to H F L, it follows, that a cylinder cannot ascend on a plane whose inclination is greater than that angle.

Cylinder-*Boring*, is the method of boring out and smoothing cylinders of brass, iron, or other metals, for pump-barrels, steam-engines, &c. &c.

Plate XXIII. *Mechanics*, is appropriated to the description of a machine for this purpose, designed by Mr. John Dixon, Maid-lane, Southwark, and erected by him at the Falcon iron-foundery.

Fig. 1. is an elevation of the machine, in the operation of boring a cylinder for a steam-engine. *Fig.* 2. is a plan. *Figs.* 3, 4, 5, parts of the machine. *Fig.* 6. an end elevation. *Fig.* 7. a section.

The machine is turned by a steam-engine, which communicates motion by means of a coupling-box, *a*, to a long iron shaft A B, turning in brass bearings, supported on iron standards C, D, bolted to the two ground sills E, F; this shaft (called the boring bar) is perforated from end to end, as is shewn in the section, *fig.* 3, and has also a slit, *b b*, *fig.* 1, through it nearly its whole length; it is turned in a lathe, and thus made a perfect cylinder. Another short cylinder, D D (in the section, *fig.* 3. and *fig.* 5.), slides easily upon the boring bar without shake, and is made to turn round with the bar, by two short iron bars, *d*, *d*, which pass through the slit, *b b*, made in the boring bar, and fit at their ends into two notches made in the ends of the short cylinder D D. E is a long screw going within the boring-bar, and of the same length; the end which enters the boring-bar, and which is not cut into a screw for some length, passes through holes made in the middle of the short bars *d*, *d*, and is held in by wedges, as in *fig.* 3.

The knives or cutters, *e*, *e*, *e*, *e*, *fig.* 4, are fixed by wedges in notches round the circumference of a cast-iron ring, *fig.* 4, called the cutter block; the inner circle, G, of the block, is of the same size as the outside of D D, upon which it is placed, and made to turn round with it, by two small wedges driven into notches *f*, *f*, made in the inside of the ring, and entering similar notches in the outside of D D.

The cylinder, H H, to be bored, is fixed firmly concentric with the boring-bar upon a frame of cast iron, consisting of several pieces, which are moveable, and can be set to hold a cylinder of any length or diameter. The first are four cast iron bars, I, I, I, I, with slits through them nearly their whole length; they are firmly bolted down to the ground sills, and support two cross bars K, K, which can be fixed at any place along the bars I, I, I, I, by screws passing through the grooves. The cross bars, K, K, have grooves through them in the direction of their length, to receive screws which fix upon each bar two uprights, L, L, at any place.

By this sliding of the two cross bars K, K, the fixtures are adapted to the length of the cylinder, and by moving the uprights L, L, nearer to or farther from each other, the cylinder is fitted in its diameter, horizontal; the weight of the cylinder is supported by blocks and wedges driven under it upon the cross bars K, K, and it is kept down by two strong wrought iron-bands, *r*, *r*, put over it, and drawn down by screws on the top of the uprights L, L.

A cross beam is fixed upon the end of the ground sills, into which an upright beam, M, is mortised, and its upper end is supported by the beams of the ceiling; the upright has a socket fixed to it, in which a nut for the screw E turns, in such a manner that it cannot move backwards or forwards, though it is at liberty to turn round freely; an iron cross, *m m*, is fixed on the nut to turn it by. The end of the screw, E, is square, and has a short cross bar, *n*, pinned on it, which has wheels at its ends, and runs upon a thick plank, N, supported on iron legs, *o*, *o*; at one edge of the plank, a piece of iron plate, *p*, is screwed and turned over at top, to form a groove in which one of the wheels run; the cross bar and plank prevent the screw from turning while it can be moved endways along the plank.

In the working of the machine, the first thing is to fix the cylinder; for which purpose the plank, N, must be removed, the screw, E, drawn out of the boring bar, the upright, M, and iron standard, D, taken away, the weight of the boring bar being supported by blocks put under the middle of it; the cutter block, and the short cylinder D D, *fig.* 3, is now put upon the boring bar, the bars, *d*, *d*, *fig.* 3, being first put through the slit, *b b*, in *fig.* 1, in the bar at its end towards D, where it is enlarged for the purpose; the cutters are fixed in the block by wedges, and adjusted, that they may all be at the same distance from the centre, and that they may bore the cylinder of the proper size. The cylinder is now put over the boring bar, and when the end of the bar comes through the cylinder, the standard, D, is replaced; the weight of the bar is now supported, and the blocks in the middle can be taken away, to get the cylinder in its place, and fix it fast, as before described. The screw, E, is next introduced into the boring-bar, and pinned into the two cross bars *d*, *d*, as in *fig.* 3, the upright M, is fixed, and the nut of the cross, *m m*, screwed upon the screw E; the plank, N, is set up, and the whole put in the situation represented in the plate, except that the cutter block is seen on the boring bar towards A.

The steam-engine is now set to work, and the boring bar thereby turned; a workman turns the cross, *m m*, and with it the nut of the screw E; as the screw is prevented from turning by the cross bar, *n*, on its end, the screw is drawn endways, and consequently the cutter block with it, until it meets the end of the cylinder, when the cutters begin to bore, forming a new smooth cylinder, somewhat larger than the old one left by the casting of the cylinder; as the cutters clear the metal before them, they are drawn further into the cylinder by turning the cross, *m m*, until they come completely through. The operation is now finished, and the cylinder is removed in the same manner as it was put in, the machine being left in pieces ready to put in another cylinder to be bored.

A great number of cutter blocks, *fig.* 4, are cast, of different sizes for various cylinders, and they all fit upon the same sliding cylinder, D D, *fig.* 3.

Damp

DAMP, *adjective* (from the Dutch *dampe)*, denotes a perceptible degree of moiſture in any thing; ſuch as in damp air, damp walls, damp apartments, damp linen, &c. The methods of aſcertaining the actual exiſtence or degree of dampneſs in any thing, an examination of the effects which it is likely to produce, and the various ways of removing it, are the objects of philoſophy, of medicine, and of civil economy; but as thoſe objects will be particularly noticed in various other articles of this Cyclopedia, ſuch as *evaporation, miſts, fogs, hygrometry, dew*, &c.; we ſhall in this place only give a compendious and ſuperficial idea of the whole. Almoſt all natural bodies, excepting metallic ſubſtances, moſt hard ſtones, vitrifications, and a few more, contain at all times a certain quantity of water; yet they are conſidered as being dry, when that quantity of water is not more than that which the affinity of the particles of the bodies to water can retain. But ſhould that affinity (*viz.* that degree of attraction between the particles of thoſe bodies and water) be diminiſhed by any adequate cauſe, or ſhould the quantity of water exceed that which the peculiar affinity of each body can retain, then the bodies are ſaid to be damp, and they will appear to be ſo, either by the mere touch of the human hand, or by the indications of hygrometers, and other inſtruments. Thus, common atmoſpherical air always contains a quantity of water which is perfectly diſſolved in the air, and is retained by every particle of the latter, in virtue of their mutual attraction of affinity. But that affinity is diminiſhed by cold, and is increaſed by heat; therefore, if a quantity of air be cooled by any adequate means, its affinity to water will of courſe be diminiſhed, and part of the water it contained will be ſeparated; forming a vapour which in ſome meaſure affects the tranſparency of the air, and is ready to attach itſelf to any other body which may be preſented to it in a ſtate fit for the abſorption of vapour. The air in that ſtate is ſaid to be damp, and an hygrometer placed in it will ſhew it to be ſo, by its uſual movement towards moiſture.

On the other hand, if cold air, which appears to be damp from the indications of hygrometers, or from moiſtening ſalts, &c.; be rendered much hotter, its affinity to water will thereby be increaſed, and the appearances of dampneſs will vaniſh.

Beſides the above-mentioned affinity, there is another power which enables bodies of every kind to retain water; and this is a ſort of ſuperficial adheſion. (See Capillary *Attraction.*) It acts moſt powerfully when a given quantity of water is expoſed to the action of a proportionately great quantity of ſurface; hence, all porous bodies have the power of retaining water to a certain degree, and under certain circumſtances. Therefore, in a variety of bodies both thoſe powers contribute to retain water at the ſame time, and ſuch moſt probably is the caſe with air itſelf.

Sometimes bodies contain water proportionate to their degree of affinity, yet other bodies will rob them of a portion of that water; and ſuch is the caſe with dry fixed alkalies, or freſh quick-lime, which will ſeparate water from air apparently very dry. This, however, only proves that certain bodies have a greater affinity to water than air or certain other bodies have

In certain circumſtances a greater quantity of moiſture is crowded upon bodies than they can retain; hence they feel damp. Thus, the air which lies contiguous to water generally contains more moiſture than the air which is more remote; but the latter by degrees abſorbs the ſuperfluous moiſture of the former, and thereby enables it to imbibe more of the vapours which riſe from the contiguous water; and thus the proceſs of evaporation goes on. But if the free circulation or communication of the air be interrupted, then the air which is confined over the water will hold a conſiderable quantity of ſuperfluous moiſture, and will thereby become damp. Now ſuch is the caſe with the air of caves, cellars, holds of ſhips, &c. when any water is contained in thoſe places. From the above ſtatement it evidently appears that heating and ventilation are the two moſt powerful means of removing dampneſs. The action of heat diminiſhes the attraction of ſolids to water, and increaſes the affinity between air and the ſame fluid. Ventilation, when the air is dryer than other bodies, removes dampneſs by diſſipating the moiſture through the atmoſphere.

From the reſult of all the experiments that have hitherto been inſtituted, it appears, that a cubic foot of air ſaturated with water, contains two grains of water at the temperature of 32° Fah. (*viz.* at the point of melting ice); it contains four grains at the temperature of 48°, ſix grains at the temperature of 60°, and eight grains at the temperature of 68°.

A remarkable circumſtance attends the mixture of aqueous vapour with air, which is, that air thus ſaturated with vapour is lighter than an equal bulk of dryer air; and this ariſes from the denſity of the vapour thus mixed, which is leſs than the denſity of the air, in the proportion of three to four, according to Sauſſure.

The explanation of ſeveral natural phenomena may be eaſily derived from the above-mentioned facts, attending, however, to other concomitant circumſtances. Thus, in a calm day, when the air is ſerene, a cold wind ſprings up from the north or from the eaſt, the cold air mixes with the warmer, their capacity for containing water is diminiſhed, a

haziness ensues, and the air becomes damp; yet sometimes the cold air is dryer on account of particular circumstances, and though a haziness may at first appear, a perfect transparency will be restored soon after.

It frequently happens, that the vapour which is separated from the air by the action of cold, remains suspended in the shape of a mist or cloud; yet at other times it descends immediately, and attaches itself to terrestrial bodies in the form of dew. But in these phenomena the action of electricity seems to be in great measure concerned. We shall have occasion to examine the nature of those phenomena more at large in other parts of this work.

The effects of damp air, damp clothing, and damp apartments, are variously modified by the climate, by the temperature, and by the customs of the inhabitants, of every particular country.

DAMP, *noun substantive*, (from the Saxon *damp*, a vapour or exhalation,) means a fog, or moist air, or moisture; but it is principally used in the plural, *damps*, to denote certain noxious vapours or exhalations issuing from the earth.

These exhalations frequently occur in mines, coal-pits, wells, and other such like excavations; but sometimes they are also to be met with near the surface of the earth, especially in the vicinity of volcanoes. The noxious quality of such exhalations, and the numerous fatal effects which they have produced, have obliged mankind to collect the various accounts of the phenomena, to investigate their origin, and to contrive methods of preventing their dire effects. But the accounts have been mostly furnished by miners, whose ignorance, whose fears, and whose sufferings, have generally involved the truth in a considerable proportion of exaggeration; yet, from a careful comparison of those very accounts, from the result of experiments instituted by scientific persons, and from the knowledge of the subject of elastic fluids, which has, of late years, been wonderfully promoted; the nature of those damps is at present pretty well ascertained, and their effects may be sufficiently accounted for; excepting, indeed, two or three strange stories, which are in need either of historical confirmation, or of a much deeper philosophical investigation.

The general effect of the damps is a contamination of the common, or respirable, atmospherical air; by the admixture, not indeed of moisture, as one might be led to understand by the name of damps, but of other elastic fluids, which are absolutely unfit for animal respiration. *Carbonic acid gas*, (formerly called *fixed air*,) *azotic gas* (formerly called *phlogisticated air*,) and *hydrogen gas*, or *inflammable air*, are the three elastic fluids which generally, if not always, produce the damps: we shall, therefore, briefly premise the principal properties of these gases; in order that the nature of the damps may be understood without much circumlocution.

Carbonic acid gas is absolutely unfit for respiration or for combustion; insomuch, that an animal confined in it, will be deprived of life rather sooner than if he were confined under water. A lighted candle or torch brought within a quantity of this gas, is extinguished as readily as if it were dipped in water. This gas is heavier than common air, in the proportion of three to two; hence, when it issues out of the earth in hollow or sheltered places, it remains for a considerable time in a stratum close to the bottom of the place. Carbonic acid gas consists of 72 parts of oxygen, and 28 parts of charcoal.

Azotic gas is likewise unfit for respiration and for combustion. Its specific gravity is very little below that of common air. It is that gas which forms about three-fourths of the atmospherical fluid, the other quarter consisting principally of oxygen air. It is produced, or rather left by itself, whenever the oxygen of the atmospherical air is absorbed, as is the case in combustion, respiration, and various other processes.

Hydrogen gas is, by itself, utterly unfit for animal respiration; but when mixed with common air, it may be breathed with impunity. In its purest state, hydrogen gas weighs rather less than the twelfth part of an equal bulk of common air; but as it is capable of holding in solution water, sulphur, phosphorus, carbon, &c so its specific gravity generally exceeds that which has been just stated; it is always, however, much lighter than common air; hence, when it occurs in mines, it is either actually issuing out of crevices, or it is lodged under the roofs of those excavations. This gas is highly inflammable, so that it may be fired by the flame of a candle, or a very small electric spark, or even by a red-hot iron; but, like other combustibles, it will burn only in contact with common, or oxygen, air; hence, if a lighted candle be presented to a certain quantity of hydrogen gas, this will burn either silently and progressively, or suddenly, and with an explosion, according as the common air is contiguous to one side of it, or is more or less intimately mixed with it. The greatest explosion takes place, when four parts of hydrogen gas are mixed with six of common air; the tint of the flame varies according to the substance dissolved in the gas. This gas is produced principally in the decomposition of water; for water consists of oxygen and hydrogen gas; from which circumstance this gas has obtained its name. After the above compendious statement of the nature and properties of the gases which produce the damps, we may proceed to describe the phenomena.

Two sorts of damps have been principally described: one has been called the *choke-damp*, from its suffocating quality; the other has been called the *fire-damp*, from its disposition to take fire, and to burn either gently, or with an explosion.

The choke-damps generally occur in old mines, called *wastes* by the miners; being such as formerly had been worked, but afterwards remained neglected. These damps are likewise frequently met with in old wells, deep cellars, and other subterranean places wherein the air has long remained undisturbed. They are formed by an accumulation of carbonic acid gas, which issues from the ground, and being much heavier than common air, remains next to the bottom, or ground, in a stratum of various depth, and more or less mixed with common air, or with azotic gas. The effects which have been produced by this sort of damp are more than sufficient to manifest the nature of the gas to which it is owing.

The persons who happen to descend within this damp, instantly lose their respiration, and fall down senseless; nor can their death be prevented, unless they are quickly removed into the open atmospherical air; but even this method frequently proves ineffectual. Several cases are recorded, where one person having been suffocated, a second went down with a view to save him; but he also fell, and sometimes even a third person met with the same fate. Persons that have thus lost their lives, on examination, have been found to exhibit all the marks of animals that have been suffocated in carbonic acid gas. One of the surest methods of ascertaining the presence of this kind of damp in a well, mine, &c. is to send down a lighted candle; for if the candle continues to burn, you may conclude that a human being is perfectly safe in it; but if the candle goes out, then

the preſence of the damp may be conſidered as certain; yet the human being may breathe, though not with perfect freedom, in air ſo far vitiated as not to be capable of ſupporting combuſtion. The miners diſtinguiſh this laſt ſtate of the air from that which is completely noxious, by the appearance of the candle; *viz.* if the flame and the redneſs or coaly part of the wick vaniſh at the ſame time, they conclude that the air is utterly unfit for reſpiration; but if the redneſs of the wick continues ſometime longer after the extinction of the flame, then they think it not very dangerous to deſcend into the place.

On account of the ſuperior gravity of the carbonic acid gas, and of its affinity to water, a greater quantity of vapour frequently remains ſuſpended in the choke-damp, than in common air; hence this damp is ſometimes viſible like a fog or miſt, and this is particularly the caſe in a cavern near Pyrmont.

It frequently happens that the ſtratum of carbonic acid gas is not higher than two or three feet; ſo that a man will be perfectly ſafe in it as long as he remains in a ſtanding poſition; but ſhould he attempt to lie down or to ſit, he would run the riſk of being ſuffocated.

The ſudden iſſue of this damp out of the earth, eſpecially when any digging has been performed, has ſometimes inſtantly killed the workmen.

In all ſuch caſes, ventilation (in whatever manner it may be practiſed) is the beſt method of diſſipating the damp. But ſhould a man be obliged to go down into a place thus infected, either for the purpoſe of ſaving another man, or for ſome other particular purpoſe, he would do well to fill a bladder with common air, and by means of a ſhort tube faſtened to the neck of the bladder, and held in his mouth, to breath that air; for a bladder thus filled will laſt him ſome minutes, during which time a great deal might be done. He might alſo take with him two or more bladders filled with common air, and furniſhed with ſtop-cocks, or merely with tubes ſtopped with corks.

Cautious miners ought always to have ſuch bladders, or ſuch like bags, filled with common air, by them; for they coſt little or nothing, and will effectually ſave their lives occaſionally.

When digging is to be performed in any place where the leaſt ſuſpicion of a ſudden iſſue of the choke-damp is entertained, it will be proper to keep a candle or lamp burning cloſe to the ground; for if any noxious gas happens to come forth, the going out of the flame will afford ſufficient warning to the workmen.

The ſudden iſſue of the choke-damp from the earth frequently occurs in the neighbourhood of volcanoes, upon old lavas, and old accumulation of aſhes or other volcanic productions. Numerous caſes of this ſort take place in the vicinity of mount Veſuvius, in Naples, where the noxious vapours, (called *mofete* by the inhabitants,) ſuddenly enter houſes, cellars, &c. to the great annoyance of the inhabitants, who, as well as other animals, are ſometimes killed by them. See ſir William Hamilton's various accounts of the mount Veſuvius and its eruptions, in the Philoſophical Tranſactions, for 30 or 40 years paſt. Some of the ſcientific perſons of the above-mentioned country have occaſionally endeavoured to aſcertain the nature of the gas which produces thoſe mofete; and from their experiments it appears, that the greateſt part of the gas is carbonic acid, but more or leſs mixed with azotic gas, and frequently accompanied with ſulphureous and arſenical vapours. A remarkable inſtance of a continual ſtream of carbonic acid gas iſſuing from the earth, occurs near the city of Naples. At about five or ſix miles from that city, near the foot of a hill, there is a famous cave called *grotta del cane* in the Italian language. This grotto is about fourteen feet long, and nearly ſeven feet high at the entrance. On the bottom of it, which is nearly on the ſame level with the adjacent external ground, there is at all times a ſtratum of carbonic acid gas or choke-damp, which is continually coming out of the earth, through the fiſſures which are pretty apparent on the ground; and where the production of ſuch gas has been remarked from time immemorial. Animals of different ſpecies, as well as human beings who ſheltered themſelves in this grotto, were at times found dead in it, in conſequence of which a door was placed to the aperture of it, which is now only opened occaſionally. The experiments uſually ſhewn to the curious who viſit this grotto, are, that of bringing a lighted torch or lighted piece of paper near the bottom or floor; the flame of which is extinguiſhed as ſoon as it comes within about 14 inches of the ground; and ſecondly that of confining a dog with its head cloſe to the ground for about a minute. The reſpiration of the animal is inſtantly affected, and its ſtrength fails, ſo as to remain apparently dead; but on being expoſed to the ambient air out of the grotto, if it be not too far gone, the poor animal will gradually recover its reſpiration and its ſtrength. It is from this uſual experiment that this grotto has obtained its name: *cane* being the Italian for a dog.

Joannes Caramuelis, in his Matheſis Nova, printed in the year 1670, relates ſome experiments made by himſelf and others upon the noxious elaſtic fluid of this grotto, which are very remarkable, conſidering the time in which they were made. He obſerves, that the ſmoke of a candle, extinguiſhed near the bottom of this grotto, is entirely retained within the ſtratum of gas; and that if part of that ſmoke happened to be driven out of the grotto, it deſcended like water falling from the edge of a tub. Had he been acquainted with the nature of carbonic acid gas, he would have eaſily underſtood that the ſmoke was retained on account of the great attraction between that gas and the aqueous particles; and that it deſcended, when driven out of the grotto, on account of the great ſpecific gravity of the carbonic acid gas with which it was combined. The ſame ingenious perſon relates another experiment, which tends to prove the acid quality of the gas concerned, which quality has long after been fully aſcertained. He and his companions placed the head of an alembic on the bottom of the grotto; and as this inſtrument was colder than the air of the grotto, which generally is pretty warm, it collected a few drops of a watery fluid, which, to the taſte of his companions, ſeemed to be acidulous. In the preſent ſtate of knowledge this experiment is eaſily explained; it being evident that the head of the alembic condenſed the watery particles from the air of the grotto, and theſe became acidulous in conſequence of their becoming impregnated with the carbonic acid gas. The ground in the neighbourhood of grotto del cane ſhews manifeſt ſigns of ſubterranean fires or fermentation, as it abounds with ſulphur, hot ſprings, emanations of ſmoke, &c.

Fire damp, though conſiderably heavier than pure hydrogen gas, is yet much lighter than atmoſpheric air. Hence where a tolerable ventilation is kept up, it ſeldom accumulates to a dangerous amount in the ſhafts, or vertical pits, that are open to the air; but in the horizontal galleries, where it occupies the upper part, forming a ſtratum, lying immediately in contact with the roof. It generally makes its firſt appearance in the cracks and crevices of the coal,

particularly where it is moist and abounding in pyrites. While it is thus oozing out, it often burns with a quiet light blue lambent flame, which, on the contact of a candle, explodes with a hissing noise, and, for a time, is extinguished or forced into an adjacent crevice. In proportion as the water is drained off, the production of this gas diminishes, so that the dryest mines are the least infested with it. Heat contributes much to its generation; hence it is generally more abundant during the summer than the winter months. If it is not cleared out of the mine, in proportion as it is produced, it soon begins to accumulate in the upper part of the galleries, on which account it is a caution well worth remembering, by those who visit a coal-pit, to hold their candles as low down as possible. The gas thus continues to increase without producing any material inconvenience to the miners, till, at length, it comes in contact with some lighted candle: the flame is immediately increased to five or six times its usual size, and in a second or two afterwards, the whole body of gas takes fire: a volume of flame and black smoke darts from the gallery into the vertical shafts, whence it rises into the air with a loud stunning explosion, throwing up, to a considerable height, men, large beams of timber, and every thing else that happens to be in its way. As soon as the explosion has taken place, the external air rushes violently into the mine to fill up the vacuum, and the residual inflammable gas again takes fire, and burns quietly for a few minutes, till it is extinguished.

When an accident of this kind happens, there are three distinct dangers to which the miners within its influence are exposed. In the first place, those who are in the gallery where the inflammation commences are scorched by the fire, and are also liable to suffer severely from the rushing in of the air to supply the vacuum caused by the explosion. Secondly, those who happen to be in the shaft, or near the mouth of the gallery, are either blown up out of the pit, or are killed by being violently forced against its sides. In the latter of these situations there is no possibility of escape; but those who are not exploded, often save their lives by throwing themselves on their faces on the ground, and covering themselves, as well as they can, with small coal, &c. till the danger is past. No particular odour is perceivable before the inflammation, but afterwards a strong and suffocating smell of burning sulphur becomes very obvious.

We shall now give a summary of the facts that were collected from the miners by Mr. Jessop, as given in the Philosophical Transactions, N° 119.

1. "Those who are in the place where the vapour is fired, suddenly find themselves surrounded with flames, but hear little or no noise; though those who are in places adjacent, or above ground, hear a very great one. 2. Those who are surrounded by the inflamed vapour feel themselves scorched or burnt, but are not moved out of their places; though such as unhappily stand in the way of it, are commonly killed by the violence of the shock, and are often thrown with great force out of the mouth of the pit; nor are the heaviest machines found able to resist the impetuosity of the blast. 3. No smell is perceived before the fire, but a very strong one of brimstone is afterwards felt. 4. The vapour lies towards the roof, and is not perceived if the candles are held low; but when these are held higher, the damp descends like a black mist, and catches hold of the flame, lengthening it to two or three hands full; and this appearance ceases when the candles are held nearer the ground. 5. The flame continues in the vault for several minutes after the crack. 6. Its colour is blue, something inclining to green, and very bright. 7. On the explosion of the vapour, a dark smoke, like that produced from firing gun-powder, is perceived. 8. Damps are generally observed to come about the latter end of May, and to continue during the heat of summer. They return several times during the summer season, but observe no certain rule."

The fire-damps generally occur in coal-mines; and in the Philosophical Transactions, N° 136, we find several accounts and observations made in digging such mines; and from these we shall compendiously extract the most useful particulars.

"After they had gone, the account says, a considerable way under ground, and were scanted of wind, the fire-damps did begin by little and little to breed, and to appear in crevices and slits of the coal where water had been before the opening of the coal, with a small bluish flame, working and moving continually; but not out of its first seat, unless the workmen held their candles to it; and then being weak, the blaze of the candle would drive it with a sudden siz away to another crevice, where it would soon after appear blazing and moving as formerly.

"This mine was neglected for a certain time; and upon a morning, the first collier that went down with his candle in his hand, the damp presently darted out so violently at his candle, that it struck the man quite down, singed his hair and clothes, and disabled him for a while. After the cessation of work for some days, in going down the first time, the fire-damps have often exploded with terrible effects."

The bad effects of the fire-damps may, in a great measure, if not entirely, be prevented by vigilance, and by a proper conformation of the excavations. In digging a mine, due attention ought to be paid to the roof of it, which ought to be shaped so as in some measure to resemble an inverted funnel, *viz.* having the highest part of it near to the shaft or shank; for, by this means, the hydrogen gas, or fire-damp, would ascend into the atmosphere as soon as it is generated; nor could it be lodged any where in so great a quantity as to produce any dangerous effects. In mines already formed, and especially when they have not been worked for a certain time, it is always proper to let down two or three lighted candles by means of a rope; and if these produce no inflammation, then a man with a candle ought to be sent down, who, after advancing a few steps into the mine, ought to lay himself down, and ought to lift up a lighted candle on the top of a pole as high as he can; for the inflammable gas which always occupies the upper part of the mine, may, in that case, be exploded with hardly any danger to the man.

When miners are actually working in a mine, the accumulation of the inflammable gas may be easily prevented, *viz.* by firing it off immediately as it issues out of the various crevices.

Ventilation is the best method of removing damps out of mines, and at the same time of giving wholesome air to the labourers; but this is hardly practicable in such mines as are furnished with one shaft or aperture. It is, therefore, always to be wished that mines of any extent should be furnished with two or more shafts in proportion to their extent. The ventilation then may be promoted by lighting a fire under one of those shafts; for by this means the air of that shaft being rarefied, will be forced to ascend, and of consequence an influx of pure atmospherical air will enter the mine through the other shaft or shafts. Several mechanical methods have also been used for the ventilation of mines. The nature of the gas which produces the fire-damp, as well as that which produces the choke-damp, has been fre-

quently subjected to philosophical experiments, with a view to ascertain both its origin and its qualities. Sir James Lowther collected the gas of the fire-damps in bladders, and thus brought it up to London, where, upon trial, he found, that on being let out of the bladders, it would take fire at the flame of a candle. But some recent experiments of Dr. William Henry, on a similar sort of gas, were performed with greater care; and their results, which we shall subjoin, are much more satisfactory.

"About the close, Dr. Henry says, of 1806, I received from the Rev. W. Turner of Newcastle-on-Tyne, two bladders filled with the fire-damp, which had been procured from a coal-mine in the neighbourhood of that town. It [illegible]

[illegible] ompressed bladder on the pipe of the funnel, after the gas had issued from it for some time. My experiments were made on the gas, about seven days after its being first collected. At that time the bladders were perfectly dry, and shewed no signs of putrefaction."

The general results of these experiments, (as stated in a memoir which was read in January 1807, before the Medi- [illegible]

[illegible] disagreeable smell. When set on fire, as it issued from the orifice of a small pipe, it burned with a dark blue flame; and a long conical glass vessel, held over the flame, was soon bedewed with moisture. Mixed with common air, it did not detonate on the approach of a lighted taper, at least in any proportion that was tried. The utmost effect was a deep blue flame, which spread quickly through the vessel, but was not accompanied with any noise. With oxygen gas, however, it exploded, and gave a loud report. On agitation with lime water, it lost about $\frac{1}{60}$th of its bulk. The nicest tests did not discover any admixture of sulphurated hydrogen. One hundred parts by measure appeared, therefore, to consist of

63.34 atmospherical air
1.66 carbonic acid
35.00 inflammable gas

100.00

"The nature of the inflammable gas was next ascertained by detonation with oxygen gas. Reducing the results to a general average, and excluding the common air, the really inflammable part of the gas required for combustion about twice its bulk of oxygen; and gave its own volume of carbonic acid. Hence the inflammable portion of the gas was *carburetted hydrogen*. From the experiments of Mr. Dalton on the gas from stagnant water, and my own obtained by distilling pit-coal, the fire-damp appears to differ very little from both these gasses.

"It was desirable, however, to repeat the analysis of fire-damp, less adulterated with common air; and for this purpose a quantity was collected (as it issued through water on the floor of a mine) in an inverted bottle, which was well corked, and tied over with a bladder. Happening to pass through Newcastle last spring, I carried this gas with me to Edinburgh; and, having no opportunity of making experiments upon it there, my friend Dr. Thomson was so good as to undertake its analysis, and to furnish me with the following results.

"From the action of nitrous gas and lime-water, the gas appeared by Dr. Thomson's experiments, to contain in 100 measures,

63.0 inflammable gas
6.5 oxygen
25.5 azote
5.0 carbonic acid

100.0."

Notwithstanding all the above-mentioned facts, experiments, and observations, the real origin of the gasses which produce the damps is by no means thoroughly understood. Indeed the origin of the carbonic acid which produces the [illegible]

[illegible] calcareous stones and other minerals; also that the action of heat easily extricates that gas from the above-mentioned minerals; so that whenever any fermentation, or any heat arising from various causes, happens to act upon such minerals, the extrication of carbonic acid is a natural consequence. But the origin of the hydrogen gas is not equally clear. It was formerly a prevailing opinion, that the inflammable [illegible]

[illegible] produces abundance of that gas. But if the hydrogen were produced by the action of pyrites upon water, a quantity of sulphur would be naturally contained in the gas, which does not appear to be the case from the above mentioned experiments of Drs. Henry and Thomson, who expressly mention their not having found any sulphuretted hydrogen in the fire-damp which they examined.

If we consider the various successive strata of different materials which almost every excavation, and especially coal and metallic mines, exhibit to our view, a much more rational mode of accounting for the production of the inflammable gas perhaps would be, by attributing the decomposition of water, and the consequent extrication of the gas, to the agency of electricity, agreeably to the phenomena of that branch of it which is at present most advantageously cultivated under the name of *Galvanic* ELECTRICITY; which see.

Having thus stated every thing which seemed to be of importance with respect to the damps, which have infested from time immemorial, and do actually continue to infest mines of almost every kind; we shall close this article with a short account of two other, much less authentic, or much less known, kinds of damp. The account (which is contained in the Philosophical Transactions, as given by the same Mr. Jessop, whom we mentioned above) is as follows:

"They call the third sort the *pease-bloom damp*, because, as they say, it smells like pease-bloom. They tell me it always comes in the summer-time; and those grooves are not free which are never troubled with any other sort of damps. I never heard that it was mortal; the scent, perhaps, freeing them from the danger of a surprise; but by reason of it many good grooves lie idle at the best and most profitable time of the year, when the subterraneous waters are the lowest. They fancy it proceeds from the multitude of red-trefoil flowers, by them called *honey-suckles*, with which the lime-stone meadows in the Peak do much abound. The fourth damp is the strangest and most pestilential of any, if all be true which is said concerning it. Those who pretend to have seen it (for it is visible) describe it thus. In the highest part of the roof of those passages which branch

out from the main groove, they often fee a round thing hanging, about the bignefs of a foot-ball, covered with a fkin of the thicknefs and colour of a cob-web. This, they fay, if it is broke by any accident, as the fplinter of a ftone, or the like, difperfeth ifelf immediately, and fuffocates all the company. Therefore, to prevent cafualties, as foon as they have efpied it, they have a way, by the help of a ftick and long rope, of breaking it at a diftance; which done, they purify the place well with fire, before they dare enter it again. I dare not avouch the truth of this ftory in all its circumftances, becaufe the proof of it is impoffible, fince they fay it kills all that are likely to bear witnefs to the particulars; neither do I deny but fuch a thing may have been feen hanging on the roof, fince I have heard many affirm it."

Dendrometer

DENDROMETER, (from δενδρον, *a tree*, and μετρεω, *I measure*,) an instrument for measuring trees. The first instrument for the purpose of measuring the trunk, the branches, and the height of a tree, without actually touching the tree, was contrived, not many years ago, by Messrs. Duncombe and Whittel, who called it the *dendrometer*, and obtained a patent for the exclusive sale of it. Since this instrument serves to measure trees from a determinate distance, other instruments, contrived subsequent to it, for the purpose of measuring the sizes as well as the distances of objects in general, though not particularly intended for the mensuration of trees, have likewise been called *dendrometers*. The principle of every one of those instruments is, that a part of the instrument forms a base of known dimensions, and the angle at each extremity of this base being measured with great accuracy, the distance of the object may be obtained by means of an easy calculation, or from a table. The distance being thus ascertained, the size of the object will afterwards be easily determined from the angle which it is found to subtend. We shall now in the first place describe Messrs. Duncombe and Whittel's original dendrometer; secondly, we shall describe another instrument lately contrived for the purpose of measuring trees but by immediate contact; and shall, lastly, give a general idea of the other instruments for measuring distances, &c. which have likewise obtained the name of *dendrometers*.

"Messrs. Duncombe and Whittel's dendrometer consists of a semicircle A, (*Plate* VI. *Surveying*, *fig.* 7.) divided into two quadrants, and graduated from the middle. Upon the diameter B, there hangs a plummet, L, for fixing the instrument in a vertical position. There is also a chord, D, parallel to the diameter, and a radius, E, passing at right angles through the diameter and chord. From a point on the radius, hangs an altimeter C, between the chord and diameter, to which is affixed a small semicircle G, and a screw to confine it in any position. The altimeter, which is contrived to form the same angle with the radius of the instrument as the tree forms with the horizon, is divided from its centre both ways into 40 equal parts; and these parts are again subdivided into halves and quarters. Upon the small semicircle, G, on which is accounted the quantity of the angle made by the altimeter and radius, are expressed degrees from 60 to 120; being 30 on each quadrant. The radius is numbered with the same scale of divisions as the altimeter. There is also a nonius to the small semicircle, which shews the quantity of an angle to every five minutes. On the back of this instrument the stock M, (*fig.* 8.) of the sliding piece is confined to the axis N which moves concentrically parallel to the elevation index, F, (*fig.* 7.) on the opposite side, to which it is affixed. This index is numbered by a scale of equal divisions with the altimeter and radius. At the end of the index is a nonius, by which the angles of elevation above or of depression below the horizon, measured upon the semicircle of the instrument, are determined to every five minutes. There is also a groove in the radius, that slides across the axis by means of a screw, I, working between the chord and semicircle of the instrument; and this screw is turned by the key O. Upon the stock, M, (*fig* 8.) is a sliding piece, P, that always acts at right-angles with the altimeter, by means of a groove in the latter. To the shank of the sliding piece is affixed a moveable limb, Q, which

forms the same angle with the altimeter as the bough forms with the body, or trunk, of the tree. This limb may be of any convenient length, divided into equal parts of the same scale with all the foregoing divisions."

"At the extremity of the fixed axis, on a centre, an index, R, with telescopic sights, works horizontally upon the moveable limb of the sliding piece. Upon this horizontal index, R, may be fixed a small quadrant, T, described with any convenient radius from the centre, on which the index moves, and divided into 90°; beginning at a right line drawn from the centre at right angles with the fiducial edge of the said index; and upon the extremity of the axis is a nonius, whereby to determine the quantity of an angle upon the quadrant to every five minutes. There are also two small circular arches, S, S, serving to keep the sights in a parallel position, each containing an equal number of degrees. Upon these arches is measured the angle, subtending a side equal to the difference of the altitudes of the observed objects, above the plane of the horizon, and whose base is the nearest distance between the perpendiculars, in which those objects are situated. The *dendrometer* is fitted to a theodolite, and may be used either with or without it, as occasion requires."

"The principal use of this instrument is for measuring the length and diameter of any tree, perpendicular, or oblique, to an horizontal plane, or in any situation of the plane on which it rests, or of any figure, whether regular or irregular, and also the length and diameter of the boughs, by mere inspection; and the inventors of it have calculated tables, annexed to their account of the instrument itself, by the help of which the quantity of timber in any tree is obtained without calculation, or the use of the sliding rule.

"The instrument is rectified by setting it in a perpendicular position, by means of the plummet, and screwing it to the staff; then the altimeter is placed in the exact position of the tree, whether perpendicular, reclining, or inclining, and is screwed fast. If the tree stands on level ground, the horizontal distance from the tree to the axis of the instrument is measured with a tape line, and the radius is moved with the key, till that distance be cut upon it by the inside of the diameter: but if the ground be slanting, the distance from the tree to the instrument is measured, and the elevation index is moved, till the point of the tree, from which the distance was measured, is seen through the sights, and there screwed fast; and the radius is moved backwards or forwards with the key, till this distance is cut upon the elevation index by the perpendicular line of the altimeter; and the horizontal line will be marked upon the radius by the inside of the diameter. In order to obtain the length of the tree, the elevation index is first moved downwards, till the bottom of the tree, cut by the horizontal wires, is observed through the sights, and the feet and inches marked by the index upon the altimeter below the point of sight, or horizontal line, are noted down: then the index is moved upwards, till the part which you would measure, cut by the horizontal wires, is seen, and the feet and inches marked on the altimeter, above the point of sight, are noted: these two quantities added together, give the exact length of the tree, which is inserted in a field-book. For the girth of the tree, the circumference in that part where the horizontal distance was taken, is measured with the tape line; and a sixth part of this circumference is added to the distance on the radius, which was before cut by the inside of the diameter, because the tape-line, in taking the distance, cannot be applied to the centre of the body of the tree; then the elevation index is lowered to that part of the tree, of which the diameter is to be taken, and is screwed fast. Set the moveable limb of the sliding-piece quite straight, and the edge of the horizontal index upon the first division of it. Turn the whole instrument about to the left hand, till you see, through the sights, the left side of the tree cut exactly by the perpendicular wires: then the instrument being fixed, move the sights only upon the sliding-piece, till you see the right side of the tree, cut also by the perpendicular wires, and you will find the true diameter, marked by the horizontal index upon the sliding-piece, which is to be entered in a distinct column of the field-book.

"For the boughs: let the distance on the radius be now reduced to its former quantity, and the elevation index moved upwards, till the bough is seen through the sights, and screwed fast. Set the moveable part of the sliding piece in a position parallel to the bough, and the edge of the horizontal index on the first division of it. Turn the whole instrument about, till you see, through the sights, the shoot of the bough, close to the trunk cut by the perpendicular wires; then move the sights, till you see the other end of the bough cut by the said wires, and note the feet and inches marked by the horizontal index on the moveable limb of the sliding piece, which will give the true length of the bough to be inserted in the field-book. And the girth of the bough may be obtained, by directing the sights to that part of it, whose girth is desired; then by moving the elevation index downwards, till you see the under-side of the bough cut by the horizontal wires, and there noting the feet and inches marked by the said index on the altimeter; after which let the elevation index be moved upwards, till the upper side of the bough, cut by the horizontal wires, is seen; the feet and inches marked upon the altimeter are to be noted as before: the former quantity subtracted from the latter, will give the true diameter of the bough, which is entered in the field-book. The true solidity, both of the body of the tree, and of the boughs, may be found from the diameter and lengths, in tables calculated for this purpose.

"The dendrometer, fitted to a theodolite, may be applied to the measuring of heights and distances of objects accessible or inaccessible, whether situated in planes parallel, or oblique, to the plane in which the instrument is placed. It may be also used for taking all angles, whether vertical, horizontal, or oblique, in any position of the planes in which they are formed; and thus for facilitating the practical operations of engineering, land-surveying, levelling, mining, &c. and for performing the various cases of plane trigonometry, without calculation; of which the inventors have subjoined a variety of examples to their account of the instrument in their treatise upon the *Dendrometer*."

Notwithstanding the ostensible extensive application of this instrument, it does not appear that the use of it has been generally adopted, which may be principally attributed to its complicated construction.

The 25th volume of the Transactions of the Society for the encouragement of Arts, Manufactures, and Commerce, contains a very useful and simple machine for the measurement of the girths of trees, to which the inventor, Mr. James Broad, gives the name of *Gauge*, or *Measure for Timber*, but which in fact is a dendrometer in the strict sense of the word, and it therefore deserves a place in the present article. This instrument is represented in *Plate* III. *Surveying*, *fig.* 9. *a a*, *a a*, Mr. Broad says, are two long pieces of well-seasoned wood, joined near the middle by a pin, *b*, going through them, forming an axis on which they move: *c*, *c*, are two pieces of brass screwed near the upper ends, on the sides opposite to each other, and projecting over to form the measuring points: *d*, is the index fastened to one of the pieces of wood at *e*, and moving freely under a small bar at *f*:

g, g, are screws with nuts, placed in the middle of the long slits of the two arms, to wedge them open, whereby the vibration is destroyed, and the arms, though light, are rendered stiff: *h, h, h, h*, are screws and nuts, to prevent the arms from splitting. With respect to the general construction, use, and improvements that may be made to it, Mr. Broad expresses himself in the following manner.

"The instrument is composed of two straight pieces of well-seasoned deal, about 13 feet long, joined together by a pin going through them, on which they are moveable; but neither the length nor thickness is of any particular consequence, as by following the directions hereafter given, they may be made of any size. A little way from the large end is a brass limb, I call the index, on which are engraven figures denoting the quarter-girth in feet and inches. To use this instrument, it is only necessary to take hold of the large end, and apply the other to that part of the tree where you wish to know the girth, opening it so wide as just to touch at the same time both sides of it, without straining it, keeping the graduated side of the index uppermost, on which the greater girth will be shewn, after allowing for the bark, by the inner edge of the brass on the right-hand leg. An operation so easy and simple, that a person of the meanest capacity might measure a great number of trees in a day.

"For taking the height of a tree, I would recommend deal rods of seven feet long, made so as to fit into ferrils at the end of each other, tapering all the way in the same manner as a fishing-rod. A set of five of them with feet marked on them, would enable a man quickly to measure a tree of more than 40 feet high, as he would be able to reach himself about seven feet.

"The improvements it is capable of, are, making a joint in the arch or scale, to enable it to shut up, (when the legs are closed) towards the centre, which would make it easier to carry. Secondly, as it sometimes happens that standing timber is sold without any allowance for bark, and at other times with a less allowance than one inch in 13, two other scales on the index might be added in such cases, one without any allowance, and the other to allow as might be agreed on. I would have added these, but thought the society would rather see it in the state in which it has been tried on a large survey, as any artist can with great ease add whatever scale he pleases. The present scale allows one inch in 13 for bark, and is calculated on the following data. The diameter of a circle, whose quarter-circumference is 26 inches, is 33.96 inches. The diameter of a circle, whose quarter-girth is 6½ inches, is 8.27 inches. To graduate the scale, the instrument is opened so as to take in at the small end between the touching points 8.27 inches, and a mark is made on the arch to denote 6 inches quarter-girth; it is then opened so as to take in 33.96 inches, and another mark is then made on the arch, to denote 2 feet quarter-girth; (these marks are made close to the inner edge of the brass on the right-hand limb:) the space between them is then divided into 18 parts, which represent inches, and are again divided into halves, for half-inches; if any notice is to be taken of quarter-inches, the eye will easily make a farther decision."

The methods of determining the distances and sizes of objects placed at a distance from the observer, depend entirely upon trigonometrical principles; and those methods for effecting that purpose, which seem to differ from trigonometrical principles, will upon examination be found to be nothing more than trigonometrical methods abridged or disguised. The general principle upon which all the operations of plane trigonometry depend, is to find out three of the six parts of a triangle, when the other three are known; (the six parts being the three sides and the three angles;) excepting, however, when the three angles are given; for in this case the proportion only of the three sides may be found; but not their actual lengths.

When an inaccessible distance is to be determined by trigonometry, the method is to measure a line or base upon any convenient place, and to observe the angles which the imaginary lines, supposed to be drawn from the extremities of that base line to a point or object at the extremity of the distance sought, make with the base; for in that case we have two angles, and one side of a triangle, whence we find by calculation the lengths of the other sides, one of which is the distance sought. If an object of any known dimensions be situated at the extremity of the distance sought, that distance may then be determined without the necessity of assuming a base line upon the place of observation; for in that case, the object itself will be supposed to form the base of an isosceles, or of a right-angled triangle; and it will be only necessary to measure the angle which that object subtends at the place of observation. The distance of an object being known, the size of the object may be easily determined by only measuring the angle which it subtends. See TRIGONOMETRY.

Now the dendrometers for measuring distances from a single station, are so constructed as to have a line of a determinate length within themselves, which serves as a base line, and two divided circular arches, or some other contrivance by which the angle which the direction of a distant object makes with that base line at each extremity of it, may be measured. But as such instruments cannot be made of an inconvenient large size, the base line which they contain is but short, and the error of the calculation is greater when the base line is shorter, and *vice versâ;* whence such instruments seldom furnish a result sufficiently exact, at least for certain purposes.

The most complete instruments of this kind are furnished with two or more speculums, (somewhat in the manner of Hadley's quadrant,) for measuring the difference of the angles at once. Upon this plan several instruments have been contrived and offered to the public by various writers. One of the most promising, though not the most compact, is described in "Gower's Supplement to the Practical Seamanship." But as we are not acquainted with the construction of any instrument of this kind, that is quite free from strong objections, we shall only subjoin a general idea of the principles upon which such an instrument may be constructed; for the use of those persons who may be desirous of employing their thoughts upon the possible improvements of that construction.

The following plans are suggested by William Pitt, esq. in the second volume of the Repertory of Arts; which, he says, may perhaps be otherwise varied and improved.

"O, (*fig.* 10.) is the object, whose distance is required. ABCDE is the instrument *in plano;* BC a telescope placed exactly parallel to the side AE. CE an arch of a circle whose centre is at A, accurately divided from E, in degrees, &c. AD is an index, moveable on the centre A, with a nonius at the end D, graduated to apply to the divisions of the arch; also with a telescope, to enable the observer to discriminate the object, or any particular part, or side, thereof, the more accurately. The whole should be mounted on three legs in the manner of a plane-table or theodolite, and furnished with spirit levels, to adjust it to an horizontal position. The instrument being placed in such position, the telescope BC must be brought upon the object O, or rather upon some particular point or side thereof;

when, being there fastened, the index A D must be moved, 'till its telescope exactly strikes the same point of the object; then the divisions on the arch E D, mark out the angle D A E, which will be exactly equal to the angle B O A. And the side B A being already known, the distance B O, or A O, may be easily determined two different ways; *viz.* 1st, by supposing the triangle B O A to be an isosceles triangle; or, 2dly, by supposing the triangle A B O right-angled at B. The accuracy of such an instrument does, *cæteris paribus*, much depend upon the length of the line A B.

"The construction of a similar instrument, on the principles of Hadley's quadrant, for naval observations, would also doubtless be an acceptable object in navigation, by enabling the mariner to ascertain the distances of ships, capes, and other objects, at a single observation; and that perhaps with greater accuracy than can be done by any method now in use.

"For this purpose, the following construction is proposed. A B C D, (*fig.* 11.) represents the instrument *in plano*. O is the object whose distance is required. At A, at C, at D, and at 3, are to be fixed speculums, properly framed and fitted; that at 3 having only its lower part quicksilvered, the upper part being left transparent, to view the object; the speculum at A being fixed obliquely, so that a line A 1, drawn perpendicular to its surface, may bisect the angle B A C in equal parts; that at C being perpendicular to the line C 2; those at E, and at 3, being perpendicular to the index E 3; and that at E being furnished with a sight. The arch D C is to be divided from D, and the motion of the index is to be measured as before by a nonius. And as the length of the line A E would tend to the perfection of the instrument, it may be constructed so as to fold up in the middle, on the line C 2, into less compass when not in use. The instrument may be adjusted for use, by holding up a staff at a distance, whose length is exactly equal to the line A E.

"To make an observation by this instrument, it being previously properly adjusted, the eye is to be applied at the sight in the speculum E, and the face turned towards the object; when the object being received on the speculum A, is reflected into that at C, and again into that at E, and that at 3 on the index; the index being then moved till the reflected object, in the speculum at 3, exactly coincides with the real object in the transparent part of the glass. Then the divisions on the arch D3, subdivided by the nonius, will measure the angle D E 3 = A O E; from which the distance of O may be determined as before."

When a straight line of at least 10 or 20 feet, may be measured at the station, where the observer is situated, and in the direction of a distant object; the size and distance of that object may be determined by the use of a most simple instrument; namely, a telescope furnished with a micrometer, and thus trees and other objects may be measured in a manner extremely commodious and sufficiently accurate. The problems necessary for this purpose, as given by Mr. Cavallo in the description of his "Telescopical Mother-of-Pearl Micrometer," will be found under the article MICROMETER.

Derby

DERBY, the county and principal town in Derbyshire, England, occupies a flat tract of land on the banks of the river Derwent, the waters of which prove eminently serviceable to the manufactures of this place. Derby was a place of repeated conflicts in the early periods of English history. In the year 874, it was occupied by the forces of Halfden, a Danish chief, whose head quarters were then at Rependune, now Repton. In 918, the Danes were still its masters; but the same year they were attacked by surprize, and completely routed by the heroic Ethelfleda, daughter of king Alfred, and princess of the Mercians. In a few years the Danes regained possession; but were again expelled in 942 by king Edmund, and about the same time dispossessed of all the principal towns in the neighbouring counties of Lincoln, Stafford, Nottingham, and Leicester. That Derby about this period was a place of great importance, is evident from its being mentioned in Domesday-book as a royal borough of Edward the Confessor, containing fourteen mills for grinding corn, and 243 burgesses, forty-one of whom held twenty-four plough-gates of taxed land. The annual rent then paid was 24*l.* When William the Conqueror obtained the crown, he gave Derby, with a great rent-roll, to his illegitimate son, William Peverell. It was afterwards granted by Henry I. to the earl of Chester, and made a corporate town; but its charter has been altered at various periods. It obtained additional privileges from Henry I. and II. Richard I. and John; in whose time the burgesses were indebted to the exchequer 56 marks, for the confirmation of their liberties. In the same reign, they were likewise returned debtors in sixty marks, and two palfreys, for holding the town of Derby at the usual fee-farm; and 10*l.* increase for all services, and having such a charter as the burgesses of Nottingham. A grant was obtained from Richard I., by which Jews were prohibited from residing in the town. In the reign of Edward III. the corporation was deprived of its liberties, and summoned into one of the king's courts, to answer "By what authority they demanded toll, yet paid none? Why they claimed the exclusive privilege of dyeing cloth, and prohibiting cloths to be dyed in every other place within ten leagues, except Nottingham? They were also to declare by what right they chose a bailiff yearly; and why they kept a fair on Thursday and Friday in Whitsun-week, and another of seventeen days at the time of the festival of St James: to explain by what authority they had a coroner; why the burgesses should not be sued out of their own borough; and wherefore they held weekly markets on Sunday, Monday, Wednesday, and Friday?" Some mutilated charters were produced in answer to these requisitions; but the liberties of the town were not restored till the inhabitants had paid a fine of 40 marks, and consented to pay an increase of rent. In the year 1611, James I. granted a new charter, confirming the privileges bestowed in former reigns, and investing the corporation with

additional liberties. By this charter the bailiffs, recorder, and town-clerk, or any three of them, were privileged to hold a court of record on every second Tuesday; to have the sole return of writs, keep a quarterly session, two courts-leet, and six annual fairs; to be toll-free throughout the kingdom; and receive toll from all, except the duchy of Lancaster, which was to pay only half the sums charged on the inhabitants of other places. In 1638, it was determined, that the authority of the two bailiffs should be vested in one person, to be chosen annually, and to be called mayor. The then bailiffs, Henry Millor, and John Hope, were the first that held that title. In 1680, the ancient charter was surrendered to Charles II., and a new one (the present) obtained at the expence of nearly 400*l*. The corporation now consists of a mayor, nine aldermen, fourteen brethren, (out of whom the aldermen are elected) fourteen common-council men, a recorder, a high-steward, and a town-clerk. The privilege of returning members to parliament is possessed by the freemen and sworn burgesses; about 700 in number. In the reign of queen Mary, a woman was burnt in this town for maintaining that the sacrament was only a memorial or representation of the body and blood of Christ, and that the elements were merely bread and wine. In 1592, the plague ravaged this town: and in 1665, when London was nearly depopulated by that dreadful calamity, it again broke out at Derby, and proved so fatal, that the country people refused to bring their commodities to the market-place. The inhabitants, to prevent a famine, raised a pile of stones, which received the name of Headless-Cross, in an open space without the town. Here the market people placed their provisions, and retired, till the buyer, who was not permitted to touch any article, till purchased, had concluded his bargain, and deposited his money in a vessel filled with vinegar. In the rebellion of 1745, Derby was distinguished as the farthest place in England to which the pretender's army reached. Their coming being expected, proper measures had been taken for the safety of the town; and nearly 600 men raised by subscription, besides 150 levied and maintained at the sole expence of the duke of Devonshire.

The situation of Derby, on the banks of the Derwent, renders it, as before observed, extremely favourable for the institution, and process, of manufactures which require the aid of water; and various works have been established in the town, or its immediate vicinity. Their success, however, has been greatly promoted by the judicious application of machinery; and mills on the most improved construction have been erected for various purposes. Those belonging to Messrs. Strutts, for the manufacture of cotton, are particularly ingenious; and the facility attained by them in working stockings, figured waistcoat-pieces, and many other articles, has eminently contributed to the extension of this branch of business. One of these mills is remarkable for its floors being all constructed on brick arches, and paved with brick, whereby it is rendered absolutely indestructible by fire. This building is six stories high, 115 feet long, and 30 feet wide; it was erected in 1793, and was the first fire-proof mill ever built.

Besides the cotton factories, the manufactures most celebrated in Derby, are those of silk, porcelain, and ornaments, &c. of Derbyshire spar and marble. The manufacture of silk is carried on to a great extent, and the number of men, women, and children employed in it is upwards of 1000. The work is chiefly performed by means of machines, or mills, of various size, and different construction. The original mill, called the silk-mill, by way of pre-eminence, being the first and largest of its kind ever erected in England, stands on an island on the river Derwent. Its history is remarkable, as it exemplifies the power of genius, and the vast influence which the enterprises of an individual has on the commerce of a country.

The extensive fabric which contains the machinery, stands upon huge piles of oak, doubly planked, and covered with stone-work, on which are turned thirteen stone arches, that sustain the walls. Its whole length is 110 feet, its breadth 39, and its height 55½. It contains five stories, beside the under works, and is lighted by 468 windows. In the three upper stories, are the Italian winding engines, which are placed regularly across the apartments, and furnished with many thousand swifts and spindles, and engines for working them. In the two lower rooms are the spinning and twist mills, which are all of a circular form, and are turned by upright shafts passing through their centres, and communicating with shafts from the water-wheel. Their diameter is between twelve and thirteen feet, and their height nineteen feet eight inches. The spinning mills are eight in number, and give motion to upwards of 25,000 reel bobbins, and nearly 3000 star-wheels belonging to the reels. Each of the four twist mills contains four rounds of spindles, 389 of which are connected with each mill, as well as numerous reels, bobbins, star-wheels, &c. The whole of this elaborate machine, for *one* only it is, though distributed through five large apartments, is put in motion by a single water-wheel, twenty-three feet in diameter, situated on the west side of the building. The whole number of wheels is about 14,000. All the operations are performed here, from winding the raw silk, to organizing or preparing it for the weavers. The raw-silk is chiefly brought in skains or hanks from China and Piedmont; that produced in the former country is perfectly white, but the produce of the latter is of a light yellow. The skain is first placed on an hexagonal wheel, or *swift*, and the filaments which compose it are regularly wound off upon a small cylindrical block of wood, or *bobbin*. To wind a single skain is the work of five or six days, though the machine is kept in motion ten hours daily; so astonishingly fine are the filaments of which it is formed. In this part of the process, many children are employed, whose nimble fingers are kept in continual exercise by tying the threads that break, and removing the burs and uneven part, some of which are the cases which the silk-worm fabricates for its own grave, or rather for its dormitory, while nature prepares it for a new mode of existence. The silk thus wound upon the bobbins, is afterwards twisted by other parts of the machinery, and is then sent to the *doublers*, who are chiefly women, stationed in a detached building, which stands on the same island, on piles like the silk-mill; and though not half so broad, is nearly thirty feet longer. Here four, seven, or ten of the threads are united into one, according to the uses for which they are designed; the fine kind going to the stocking weaver; the others to the manufacturers of waistcoat-pieces, &c.

The manufacture of porcelain was originally established at Derby about the year 1750, by the late ingenious Mr. Duesbury; but the most considerable improvements have been effected since his decease, through the judicious methods employed in preparing the paste, and increasing the beauty of the decorations. The ware itself is not of equal fineness with the French and Saxon; though its workmanship and ornaments are far superior. The paintings are, in general, rich and well executed, and the gilding and burnishing exceedingly beautiful. The body of the semi-vitreous ware, called porcelain, is fine white clay, combined with different proportions of fluxing matter. The best kind is absolutely infusible, and takes for its glaze a vitreous sub-

ſtance, without a particle of lead. When the paſte is duly prepared, by grinding and other operations, it is conſigned to the workman, whoſe dexterity produces a variety of beautiful forms from the ſhapeleſs maſs delivered to him. Round veſſels are uſually made by a man called a *thrower*, who works them on a circular block, which moves horizontally on a vertical ſpindle. From him they paſs to the lathe, and are reduced to their proper thickneſs and form at the end of an horizontal ſpindle. Afterwards they are *finiſhed*, and *handled* if neceſſary by other perſons, and are then conveyed to a ſtove where they remain till the moiſture is entirely evaporated, when they become fit for baking. Oval veſſels, ſuch as tureens, tea-pots, &c. aſſume their form by being *preſſed* into moulds of plaſter, or gypſum, by hand. The *ſaggars*, or caſes, in which the articles are burnt, are various in ſize and dimenſions. Theſe are ſet in the kiln or oven, one upon the other, and when piled up nearly to the top, have ſome appearance of piles of cheeſe. When the kiln is full, it is carefully cloſed, and the ware baked by the admiſſion of heat through horizontal and vertical flues; this is the firſt baking, and the porcelain in this ſtate is vulgarly called biſcuit. It is then dipped in glaze of about the conſiſtence of cream, and carried to the glaze kiln, where it is again baked, but in a leſs degree of heat than before. The ware is now delivered to the painters, who, with colour prepared from mineral bodies, ornament it with landſcapes or figures, according to the required patterns. After this proceſs, it is again conveyed to the kiln, and the colours vitrified, in order to fix and give them a proper degree of luſtre. Every coat, or layer of colour, requires a freſh burning; once or twice is ſufficient for the ornaments of the common porcelain, but the more elaborate decorations render it neceſſary for the colours to be laid on, and undergo the action of fire ſeveral times, before they obtain their full effect. This completes the proceſs of thoſe articles that have no gold in their pattern; but where this addition is wanted, they are pencilled with a mixture of oil and gold diſſolved, or thrown down by quickſilver aided by heat, and once more committed to the kiln; here the gold reaſſumes ſolidity, but comes out with a dull ſurface, which is quickly rendered brilliant by rubbing with blood-ſtones, and other poliſhing ſubſtances. The porcelain is now ready for uſe, but the latter part of the proceſs requires conſiderable care, as the gold, when not ſufficiently burnt, will ſeparate in thin flakes, and when over-fired, will not receive a proper poliſh. The higheſt finiſhed ware in this manufactory is frequently returned to the enamel kiln, where the colours are fluxed ſix or ſeven times; the beſt only are here finiſhed for ſale. The making of biſcuit figures, or white ware, is peculiar to this manufactory; and the pieces are ſuppoſed to be equal in beauty and delicacy to any of a ſimilar kind made in Europe. Here the lathe is of no uſe, the figures being all caſt in moulds of plaſter or gypſum, into which the materials are poured, having previouſly been reduced to a liquid of the conſiſtence and appearance of thick cream. The water contained in the mixture is quickly abſorbed by the plaſter, and the paſte becomes ſufficiently hard and tenacious to part freely from the mould. The various parts of the figures, as the head, arms, legs, &c. are caſt in ſeparate moulds, and when dried and repaired, are joined by a paſte of the ſame kind, but thinner than the former. The articles are then ſent to the kiln, and after undergoing a regular and continued heat, come out extremely white and delicate.

The original ſilk-mill, erected by Mr. Crochet, and now called the old ſhop, was afterwards converted into a cotton factory, but is at preſent in the occupation of Meſſrs. Brown and ſon, who employ it for cutting and poliſhing marble, and manufacturing the Derbyſhire fluor ſpar, or blue John, and gypſum, into a variety of beautiful ornaments, as urns, vaſes, columns, obeliſks, &c. The machinery applied to execute theſe purpoſes is of very ingenious conſtruction; and the lathes are ſo contrived, by the aſſiſtance of a reverſe motion, that they can readily be made to revolve either ſlower or faſter, as the deſign or quality of the ſubſtance under manufacture may require. They may likewiſe be ſtopped at pleaſure, without impeding the motion of any other part of the works. When the blue John is to be made into a vaſe, or any other ornamental form that renders the uſe of the lathe neceſſary, it is carved with a mallet and chiſſel, into a rude reſemblance of the object intended to be produced, and being afterwards ſtrongly cemented to a plug or chock, is ſcrewed upon the lathe. A ſlow motion is then given to the work, and a bar of ſteel about two feet long, and half an inch ſquare, properly tempered, and pointed at each end, is applied to the fluor, on which water is continually dropping to keep the tool cold, preſerve it from friction, and enable it more readily to reduce the ſubſtance upon which it acts. As the ſurface becomes ſmoother, the tool is applied with more freedom, and the motion of the lathe accelerated, till the fluor has aſſumed its deſtined form. When the turning is completed, pieces of grit-ſtone, of different degrees of fineneſs, are applied with water to bring the article to a proper ground for poliſhing with fine emery, tripoli, and putty, or calx of tin. Theſe means are continued till the fluor is incapable of receiving a higher degree of poliſh; which is known when water thrown on it will no longer increaſe its luſtre. The advantage of the lathe ſet in motion by water over thoſe worked by the foot, is ſaid to be particularly conſpicuous in forming hollow vaſes, or articles of equal delicacy. By the uſe of the foot-lathe the fluor was frequently broken, and without extreme care, its laminated texture always diſturbed; but the greater ſteadineſs given to the machinery by the water-wheel, operates as an effectual preſervation from theſe inconveniences. The great eaſe with which a ſlow or quick motion can be produced by the uſe of the water lathe, is alſo an additional advantage, and tends conſiderably to increaſe the elegance of the ornaments. The ſame wheel which gives motion to the lathes for manufacturing the fluor-ſpar, &c. is likewiſe applied to work the machinery for ſawing and poliſhing marble. On the vibrating poles to which the cranks are fixed are ſliding boxes, containing ſets of ſaws, which are nothing more than thin plates of ſoft iron, that drop as they cut the marble. Theſe are ſupplied with ſand and water; and being moveable with ſcrews, may be arranged at different diſtances, ſo that the ſlabs may be cut of any thickneſs. A ſet of ſaws conſiſts of a different number of plates, ſo that the block to which they are applied may be ſeparated at one proceſs into as many ſlabs as may be thought neceſſary. The ſlabs thus ſawn, are taken to the poliſhing bed, which has four wheels that move on a gangway with a very ſlow motion given to it by a worm and a crank. One of the ſlabs being fixed on this bed, another is faſtened above it to an arm attached to a vibrating pole, that works with a quick motion in a tranſverſe direction. The ſlabs thus moving in contact with each other, and being ſupplied with ſand and water, ſoon acquire a level ſurface, when finer materials are employed to increaſe their ſmoothneſs, and give them a higher poliſh.

Derby is divided into five pariſhes, each of which has a church. The principal ornament of the town is All-Saints church: yet, reſpectable as it is, it diſplays a remarkable inſtance of architectural incongruity. The tower was

erected in the reign of Henry VIII., and its upper part is richly ornamented with tracery, crockets, high pinnacles, and battlements; but the body is Grecian, and the interior is particularly light and spacious. The roof is supported by five columns on each side. The design of the body of the church was executed by Gibbs, the ingenious architect of St. Martin's in the Fields, London. The money for building it was chiefly procured through the indefatigable exertions of the then minister, Dr. Michael Hutchinson, whose zeal and success in this work are recorded on a tablet to his memory, placed against the south wall within the church. On the south side of the chancel is the monument room of the Cavendishes; and many of that illustrious family are buried in the vault beneath. In this repository is a splendid mural monument to the memory of the celebrated countess of Shrewsbury; it was constructed in her life-time, and under her inspection. Among other monuments deserving of notice, is one to the memory of William, earl of Devonshire, who died in 1628, and Christian, his countess. Another neat monument, by Nollekins, displays the medallion and arms of William, earl of Besborough, who died in 1793: and on a mural monument, by Rysbrach, to the memory of Caroline, countess of Besborough, who died in 1760, is a well executed figure of that lady. Against the wall, on the north side of the church, is a curious memorial of Richard Croshaw, who was the son of a poor nailor in this town, and went to London in a leathern doublet to seek his fortune: possessing industry and perseverance, his endeavours proved successful; and having attained considerable affluence, he bequeathed upwards of 4000*l.* to the corporation of Derby, for the maintenance of lecturers, the relief of the poor, and other benevolent purposes. He died in 1631. The other four churches of this town are respectively dedicated to St. Alkmund, St. Peter, St. Werburgh, and St. Michael. The first of these is supposed to have been founded at the beginning of the ninth century, in honour of Alkmund (son of Alured, the deposed king of Northumberland) who was slain in battle while endeavouring to reinstate his father.

The principal public buildings in Derby are a county hall, a town hall, a county gaol, an elegant assembly room, and a theatre. The county hall, which is a large but heavy building of free-stone, was finished in the year 1660. The town hall, built by the corporation in 1730, is a handsome structure. The county gaol was erected about 1756, at the expence of the county, aided by a donation of 400*l.* from the duke of Devonshire: it is situated on the east side of the town, near the upper end of Friar gate, and is a very respectable building, well adapted for the purpose of its destination: the front is from an excellent design, displaying solidity and strength, without that affectation of incongruous ornament so frequently exhibited in modern buildings of similar character. The assembly room is of stone, and is situated on the north-east side of the market place: the foundation was laid in 1763; but the edifice was not completed till 1774. The theatre stands in Bold lane, is built of brick, and was erected in 1773.

Derby is a very improving and populous place; and though the buildings have been continually increasing for the last twenty years, they are yet insufficient for the convenience of the inhabitants. Fresh ground is frequently broken up for new houses, which are mostly let before they are completed: the number of houses, as ascertained by the late act, was 2,144. that of the inhabitants 10,832; but both are increasing, and there is reason to believe, will keep pace with the progressive improvements of the town, and the augmentation of its trade. Various branches of business, besides the manufactures already mentioned, are carried on to a considerable extent, and several new works of magnitude have lately been established. On Nun's green a bleaching-ground has been opened, in which the processes are performed according to the improved methods introduced by the advancement of chemistry: to aid the operation, a small steam-engine has been erected. A mill for slitting and rolling iron for a variety of purposes; a large furnace for smelting copper ore, with a machine for battering and rolling the copper into sheets; a red lead manufactory; a mill for making tinned-plates, &c. are also existing in this town or its immediate vicinity. Among the modern improvements of Derby, may be included the lighting and paving of the streets, and the removing of those obstructions that prevented a free passage. These purposes were effected by an act passed in 1792, which appointed commissioners with full power to levy a small rate on the inhabitants, and likewise to sell all the common land belonging to Nun's green; the sums thus produced to be applied in defraying the necessary charges. Since the above year, several of the bridges that were built across the Markeaton Brook have been removed, and three new ones, of stone, erected by subscription. An elegant bridge of three arches has likewise been built over the Derwent; and, together with the silk-mill, the weirs, and the broad expanse of the river, forms a very pleasing prospect on entering the town from the Nottingham road.

Numerous bequests for the relief of the poor have been made at different times by benevolent persons. One of the most considerable charities is the Devonshire alms-house, founded by the countess of Shrewsbury in queen Elizabeth's reign, for the support of eight men and four women: the old house was taken down about twenty years ago, and the present erected by the duke of Devonshire. Science and literature meet with great encouragement at Derby: this may, in some degree, be ascribed to the Philosophical Society established here about the year 1772, through the fostering patronage of the late Richard French, esq. and Dr. Darwin, the latter of whom for many years made this town his residence. Several book-societies have also been instituted; and to the credit of the individuals composing them, the works purchased are chiefly of a scientific and philosophical tendency.

Derby, previous to the dissolution of religious houses, contained a monastery dedicated to St. Helen, founded by Robert de Ferrariis, second earl of Derby, about the middle of the twelfth century; a small Benedictine nunnery, founded soon after the former by an abbot of Derby, and dedicated to St. Mary de Pratis; a priory of Dominicans, or Black Friars, founded towards the close of the thirteenth century; and a cell of Cluniac monks, founded by Waltheof, a Saxon nobleman, dedicated to St. James, and given early in the twelfth century to the abbey of Bermondsey, in Southwark. Here were also an hospital dedicated to St. Leonard, and a maison-dieu, both instituted for the reception of lepers.

Derby is situated 126 miles N.W. from London; it has a weekly market on Friday, and seven annual fairs.

The celebrated astronomer John Flamstead, is considered by some authors as a native of this town; an opinion which, though controverted, is favoured by the circumstance of his father residing here.

The vicinity of Derby furnishes a variety of agreeable walks, where the inhabitants may enjoy a salutary exercise, and a succession of prospects distinguished by the softer features that attend cultivation. On Windmill-hill, at a short distance from the town, a neat prospect-house has lately been erected by —— Robinson, esq. from which the views over the adjacent country are very extensive. Hutton's History

of Derby, 8vo. Pilkington's History of Derbyshire, 2 vols. 8vo. Beauties of England and Wales, vol. iv.

DERBY, a township of America, in Orleans county, Vermont, on the N. line of the state, on the E. shore of lake Memphremagog.—Also, a post-town in New Haven county, Connecticut, on the point of land formed by the confluence of Naugatuck and Housatonick rivers. This town was settled in 1665, and is now divided into two parishes, and has an academy. It has a considerable trade with the West Indies, and in its vicinity are mills on the falls of Naugatuck, and iron as well as other works on Eight-mile river, that falls into the Housatonick, which is navigable for 12 miles to this town. It has 1878 inhabitants.

DERBY, or DARBY, *Upper* and *Lower*, are situated in Delaware county, Pennsylvania; the former containing 862, the latter 980 inhabitants; seven miles S.W. of Philadelphia.

DERBY *neck*. See BRONCHOCELE.

DERBY *Canal* is the parliamentary name of a navigable canal in the county of Derby, which was completed in the year 1794, between the Trent river at Swarkstone, and Little Eaton, with a rail-way extension thence to the collieries at Smithey-Houses, near Denby, and a branch from the same to Horsley and Smalley Mills collieries. There is also a branch from the town of Derby to the Erewash canal, near Sandyacre. See CANAL.

DERBYSHIRE is a county situated nearly in the middle of England, at an equal distance from the eastern and western seas. It is encompassed by Yorkshire and Cheshire to the north, and Staffordshire, Leicestershire, and Nottinghamshire to the east, west, and south. The area is supposed to measure about 55 miles from north to south, and 38 in an opposite direction, and comprises nearly 720,640 acres of land. Of these above 500,000 are cultivated arable and pasture, whilst the remainder consists chiefly of bleak mountainous regions, and open commons. The whole county is divided into six hundreds, and contains 11 market towns, and 136 parishes. These comprehend 33,191 houses, and about 161,142 inhabitants.

The northern and southern parts of this county exhibit a striking difference and contrast in geographical features: as the former abounds with hill and vale, and the latter presents a flat surface. The higher region is denominated the High Peak, and the latter the wapentake, or Low Peak. Among the chief eminences in this district are the mountains of Ax-edge, and Kinder-scout. The former is situated near Buxton, and was calculated by Mr. Whitehurst to be about 2100 feet higher than the town of Derby, and 1000 feet above the valley in which Buxton-hall stands: the elevation of Kinder-scout, though not precisely ascertained, is supposed to be greater. The High Peak is a region of bleak barren heights, and long extended moors, interspersed with deep vallies, through which the small streams take their course. Here the scenery is in many parts romantic and sublime; though, on the whole, inferior in picturesque effect to that of other mountainous countries. Beauty, indeed, is only resident in the vallies; the high ground appearing dreary and destitute of entertainment; and in many situations not a single house or tree is to be seen, to divert the eye of the traveller, or relieve the weariness that arises from the contemplation of sterility and nakedness. The Low Peak abounds with eminences of various height and extent. Brassington-Moor, Alport, near Wirksworth, and Crich-Cliff, are the most elevated, and command very extensive prospects: from Alport, on a clear day, the Wrekin in Shropshire may be distinguished. On the east side of the county there is also a high ridge of considerable extent, beginning to the south of Hardwick, and continuing in another direction to the extremity of the county, where it enters Yorkshire. The southern part of Derbyshire is in general pleasant and well cultivated, but presents no particular variety of scenery. The mountainous part of this county is distinguished from the rest, by the greater quantity of rain which falls in it. At Chatsworth, which is by no means the highest tract, about 33 inches of rain have been found to fall annually at a medium. The High Peak is peculiarly liable to violent storms, in which the rain descends in torrents, so as frequently to occasion great ravages in the lands; it is also subject to very high winds. These causes, together with the elevation of the country, render it cold, so that vegetation is backward and unkindly. Some kinds of grain will not grow in the Peak, and others seldom ripen till very late in the year. The atmosphere is, however, pure and healthful, and the higher situations are generally free from epidemic diseases, though agues and fevers sometimes prevail in the vallies. One disease is, however, endemic in these parts, and even as far south as Derby; this is the Bronchocele or Derby-neck: it is an enlargement of the glands of the throat; and is a degree of the same disease that is known in the Alps, and other mountainous tracts. It is also prevalent in some parts of Sumatra and the East Indies.

The most common soil of Derbyshire is a reddish clay, or marl; the southern district is in general composed of it, having little or no stone near the surface: but some parts of this tract are interspersed with small beds of sand or gravel; and in most situations, land of a blackish colour, and loose texture, is sometimes met with, continuing through an extent of from 50 to 200 acres. This kind of soil is likewise found throughout the southern and middle part of the extensive tract of limestone, which lies on the north-west side of the county. Its colouring principle is iron; but its quality is very various in different situations: in some it contains much calcareous earth; in others it does not effervesce with acids. The large tract on the eastern side of the county, which extends from Stanton, Dale, and Morley, to the borders of Yorkshire, and abounds with coal, is covered with a clay of various colours, black, grey, brown, and yellow, but principally the last; and is in some places mixed with a large proportion of sand. Similar soil is also met with in the northern extremity of the county; and in some parts where gritstone is found; but in the latter situations, the land is more frequently of a black colour, and bituminous quality. In the vallies, near the banks of the larger rivers, the soil is very different from that of the adjacent parts, and has been evidently altered by the depositions from the inundations. Peat bogs exist in the north parts of the county, even on the highest mountains; and in some of them, trees have been found nearly perfect. Barley is much cultivated in many parts, but particularly in the parishes of Gresley and Repton, where the farmers are induced to grow it, by the consumption of malt in the neighbouring town of Burton, whose famous ale has acquired such extensive celebrity. The whole produce has been calculated at about 5000 quarters annually. On the eastern side of the county the land is chiefly under tillage; but the midland tracts have a mixture of pasture and arable, according to situation: the moors in this district are in a course of progressive improvement. In the High Peak the grounds are chiefly appropriated to the grazing and breeding of cattle; very little corn, besides black oats, being grown: on the more elevated parts, sheep of the smaller horned kind are fed: the mutton is excellent. Little attention has been paid to the cultivation of artificial grasses: but an uncommon species of culture, as a field crop, here practised is that of chamomile: about 200 acres are devoted to its

growth. A loamy foil is chofen for its cultivation, and, after the ground is well prepared by thorough cleanings, about the end of March, the roots of an old plantation are taken up, and divided into fmall flips, which are planted in rows about eighteen inches afunder, and at about the fame diftance in the rows. The plants are kept clean by frequent hoeing and weeding with the hand. In September the flowers are fit to gather: their perfection depends upon their being fully blown, without their having ftood fo long as to lofe their whitenefs; the flowering continues till ftopped by the frofts. The gatherings are repeated as often as fucceffions of flowers appear; but this depends very much on the feafon, dry open weather furnifhing more fucceffions than wet or dull weather. When the flowers are gathered, they are carefully dried, either in kilns very moderately heated, or on the floors of boarded rooms, heated by flow fires: the object is to keep the flowers white and whole, and this is beft effected by drying them as flowly as poffible. The produce varies from two hundred weight, or even lefs, to four, five, and in fome few inftances, fix hundred weight *per* acre. The price has alfo varied from 2*l.* to 7*l.* *per* cwt. The plants ufually ftand three years, of which the firft affords the fmalleft produce; and the fecond the greateft and beft. When the fame plants are continued beyond three years, the ground becomes foul, and the flowers weak. When dried, the flowers are packed in bags; and afterwards fold to perfons in the neighbourhood, who tranfmit them to the druggifts in London.

For the botanical character and medicinal properties of chamomile, fee ANTHEMIS.

The inclofures of Derbyfhire are very numerous, and are annually extending. Within the laft twenty or twenty-five years, more than one-fourth of the county has been inclofed, and the rent in many inftances nearly doubled. The fouthern part, and the wapentake, are almoft wholly in this ftate; but the grounds in the High Peak are chiefly open. The former diftricts are tolerably well provided with timber, but in this refpect the plantations of Kidlefton park are unrivalled by any in the county.

The manufactures which are carried on in Derbyfhire are various and extenfive. With Nottinghamfhire and Leicefterfhire, it partakes in the manufacture of ftockings; with Yorkfhire, in that of iron, and of woollen-cloth; and with Lancafhire, in that of cotton. To thefe may be added the manufactures of filk and of Derbyfhire fpar, the latter of which may be confidered as peculiar to this county. The bufinefs of hofiery is chiefly confined to the parts that border on Nottinghamfhire, and to Litton, near Tidefwell. The number of frames employed, including thofe on which filk and cotton ftockings are wrought, has been calculated at about 1350. Wool is moftly manufactured in the High Peak, adjacent to Yorkfhire. Cotton is manufactured in different modes, and in various parts of the county; but the principal factories are at Cromford, Belpar, and Derby: in the former the cotton is prepared by the machine invented by the late fir Richard Arkwright; from fixteen to twenty machines, on the fame model, are alfo employed in other parts of the county. The filk and fpar manufactures are nearly confined to the town of Derby.

Befides the fources of labour derived from the branches of commerce above enumerated, the mines of lead, iron, calamine, and coal, afford employment to many inhabitants of this county. The lead mines conftitute a confiderable part of the natural riches of Derbyfhire, and fome of them have probably been worked through a long fucceffion of ages: their produce was formerly of greater value than at prefent; as the veins become poorer, the deeper the mines are excavated. Camden imagined that Derbyfhire was alluded to by Pliny, where he fays, "In Britain lead is found near the furface of the earth in fuch abundance, that a law is made to limit the quantity that fhall be gotten." However this may be, we have decifive evidence that the Romans had lead works in this county, as feveral pigs of lead have been found with Roman infcriptions. The firft of thefe was difcovered on Cromford Moor, in the year 1777, on which the following fentence was legible: IMP. CAES. HADRIANI. AVG. MEI. LVI. That the lead mines of Derbyfhire were known to the Saxons, is apparent from the mine near Caftleton, called *Odin*, from the name of one of their deities: the fame circumftance implies that it was opened previous to the introduction of Chriftianity into Britain. It appears alfo, that there were lead mines in the wapentake of Wirkfworth, in the year 835; for at that period Kenewara, abbefs of Repton, granted her eftate at Wircefworth to Humbert the alderman, on condition that he annually gave lead of the value of 300 fhillings to archbifhop Ceolnoth, for the ufe of Chrift-Church, Canterbury. At the time of the Norman furvey, the bufinefs of the lead mines was undoubtedly carried on to a confiderable extent, as no lefs than feven mines in this county are mentioned in the Domefday book.

Veins of lead ore are diftinguifhed on account of their various pofitions in the earth, by the different names of pipe, rake, and flat works. Pipe-works lie between two rocks or ftrata, yet feldom follow any regular inclination, but fill up fiffures, the lines or branches running parallel to each other, and more or lefs horizontally. The veins are fometimes twenty or thirty yards wide, and fometimes not more than two inches: they moft commonly have toad-ftone in the vicinity, either above or below. Rake, or perpendicular veins, are found in the clefts and chafms of the lime-ftone; and confequently, inftead of extending uniformly between the fame ftrata, they follow the directions of the cavities, and fometimes penetrate 150 or 200 yards into the earth. The flat-works bear a great refemblance to the pipe; yet difagree in fome circumftances. The principal leader or ftem in the pipe is accompanied with many branches, but the flat has none; the latter fpreads wider, yet feldom extends more than 100 yards. It is alfo found near the furface, and in the folid rock. The miners are divided in opinion whether the pipe or rake veins are moft prevalent.

The greateft impediments to working the mines are foul air, and water. To relieve them from the firft, a pipe or tube is generally introduced down the fhaft, and extended along the roof of the gallery, to the place where the work is carried on. To remove the water many adits, or, as they are here termed, foughs, have been driven from the bottom of fome neighbouring valley, and made to communicate with various works by different channels or galleries. The longeft adit in Derbyfhire is at Youlgrave, running from the Derwent to Alport, and called the Hilcar fough. This coft upwards of 50,000*l.* It relieves a confiderable number of mines, and is nearly four miles in length. Another, and one of the moft confiderable at Wirkfworth, is called Cromford fough. This is full two miles in length, and was driven at an expence of 30,000*l.*

The annual produce of lead from the Derbyfhire mines cannot be exactly afcertained, but may be eftimated at an average of between 5000 and 6000 tons. The trade has been generally confidered to be on the decline, as the increafe of depth renders the mines more difficult to be worked, as well as more expenfive; yet, from the improvements that have been made in the art of fmelting, and the more effectual mode employed to relieve the mines from water, by the driving of

new levels, and the erection of some improved fire-engines, advantages have been obtained, which, to a certain extent, counterbalance the augmented expences.

Iron-stone, or oxyd of iron, is found in this county in great abundance; it occurs throughout the whole district in which coal has been discovered, the Chinley hills excepted. The depth at which it lies from the surface is various, but frequently, from the great dipping of the strata, it *bassets* out *to-day*, as they here term it. In this case a hole is made like the shaft of a coal-pit, which is gradually enlarged as it is carried deeper, till the cavity assumes the shape of a bell. These are seldom sunk lower than eighteen or twenty yards; when at that depth fresh ground is broken, and new openings made, of similar depth and form. From this practice the land receives greater injury by working iron mines, than those of coal, and it is, therefore, not judged expedient to dig for iron ore, unless the beds are very rich. Their thickness varies from two to twelve inches. The quantity of iron annually produced in this county amounts to between fifteen and sixteen thousand tons. See Iron.

The chief places at which calamine is obtained, are Castleton, Cromford, Bonsall, and Wirksworth. It occurs at various depths, but is generally found near a vein of lead ore: sometimes the two minerals are mixed, or run a considerable way by the side of each other; but more frequently, one ceases where the other begins, and a good vein of both is never found in the same place. The quantity prepared annually in this county is about 500 tons. In the crude state, its value is from three to four pounds a ton; but when refined, it is sold at nine or ten pounds. By the various processes it undergoes before it becomes saleable, it loses about eight parts in twenty. See Calamine.

Coal was obtained in Derbyshire so early as the reign of Edward II., both in the liberties of Norton and Alfreton. This is evinced by the grant made to the monks of Beauchief abbey by the lord of Alfreton, Thomas de Chaworth, who gave them licence to supply themselves with this substance in any quantity they thought proper, from either of the above places. It is found at different depths, and in some situations several beds are perforated by one shaft; but the upper ones are of inferior quality, and seldom worked. Here, as in Cumberland, the vein of coal is frequently separated, or broken, by some intervening substance, mostly clay; and the coal on one side is sometimes found lifted up or cast down ten or twenty yards from its level, on the other. Besides the home consumption of coal, which is very great, large quantities are annually sent to Sheffield; and by the different canals more is conveyed into Leicestershire, Nottinghamshire, Lincolnshire, and Northamptonshire.

Derbyshire also abounds with metallic ores, fossils, and various mineral substances; but it would exceed our limits to particularize all. Those who wish for such information are referred to Mawe's Mineralogy of Derbyshire, and the Beauties of England and Wales, vol. iii.

The mineral and medicinal waters of Derbyshire are, as might be expected in a country abounding with fossils, numerous. All those of a chalybeate and sulphureous nature arise in beds of shale, and probably derive their impregnation from this substance; the warm springs also are observed to appear near these beds, though they break out in the stratum of lime-stone almost exclusively. The most celebrated warm springs are those at Matlock and Buxton; they occur likewise at Stony Middleton; and Middleton, near Wirksworth, had formerly a spring of this description, which was cut off some years since by driving a sough to remove the water from some lead mines in the vicinity. Those of Matlock and Buxton have obtained much celebrity for their medicinal properties, and are annually visited by a considerable afflux of company, who resort to them as well for pleasure as for health. The natural history of the Matlock and Buxton waters occupied much of the attention of the late Dr. Darwin, whose death has deprived society of one of its most valuable members, and science of one of her most distinguished sons. His principal observations on this subject were contained in a letter written to the Rev. Mr. Pilkington, and published in the "View of Derbyshire." Among the arguments which have been adduced respecting the origin of warm springs, the doctor favours the following: "That the water of these springs is raised in vapour by subterraneous fires deep in the earth, and that this vapour is condensed under the surface of the mountains in the vicinity of springs."

Amongst the sulphureous waters of Derbyshire, that which is highest in repute rises in the park of lord Scarsdale, at Kedleston. In a glass it looks very clear and transparent; but in the well it appears of a blackish blue colour, tinged with purple, and any substance thrown into it assumes the same appearance. It is principally valued for its antiscorbutic qualities. When taken inwardly it acts as a diuretic, and has given relief to persons afflicted with the gravel. It has also been found efficacious, from external application, in various cutaneous diseases, but more especially in ulcerous complaints. The temperature of the spring is about forty-seven degrees. Several other sulphureous springs rise in different parts of the county, but have hitherto undergone very little examination.

The chalybeate waters are numerous, but the most celebrated spring of this nature is at Quarndon, about three miles from Derby. Persons of a weak and relaxed habit have been much benefited by its use: when taken in sufficient quantity, it generally operates as a cathartic; yet to produce this effect, exercise is sometimes necessary. Its temperature is nearly forty-nine and an half. Within 200 yards of the warm spring at Buxton, there is a chalybeate water of properties nearly similar to that at Quarndon. Other chalybeate waters are found at Morley, Chesterfield, Tibshelf, Duffield, and Bradley.

In the liberty of Heage, about midway between Crich and Belpar, is a martial vitriolic spring, the only one that has yet been found in this county. It is situated in a black boggy soil, and was accidentally discovered about thirty six years ago.

The principal rivers of this county are the Trent, the Derwent, the Dove, the Wye, the Errewash, and the Rother.

Derbyshire is situated in the diocese of Lichfield and Coventry, and sends four members to parliament, *viz.* two for the county, and two for the county-town. Pilkington's View of Derbyshire, 2 vols. 8vo. Mawe's Mineralogy of Derbyshire, 2 vols. 8vo. Beauties of England and Wales, vol. iii.

Design

Design, in the *Weaving Manufactures*, signifies the pattern of any ornamented piece of cloth, when the ornaments are woven in the loom along with the fabric. A species of paper is used to lay down these ornaments to a scale, which is called design paper, and which serves to direct the weaver in his subsequent operations. In every species of ornamental weaving, the whole design is effected by the leaves of clasped twine, which move the various threads of that part of the yarn, which is stretched in the loom, and which is called the warp. These leaves are called heddles in Scotland, healds in Lancashire, and may probably be known by other names in different parts of the country. The paper upon which the design is to be drawn, is ruled from top to bottom with a number of parallel lines, the intervals between which represent certain portions of warp. These, being again crossed by other parallel lines at right angles, the latter represent that part of the yarn which is inserted by the shuttle, and which is called the woof or weft. The design-paper, when ruled, has the appearance of a number of small squares, and in these the design is inserted with a black lead pencil, or with any kind of water colour, very frequently with vermilion, or red lake. Every interval upon the paper may be supposed to represent either one or more threads. When it will not occupy too much space, and when the design requires particular delicacy of shape, the most accurate way is to make every interval represent only one thread. At other times it frequently represents two, and sometimes more.

The five figures in *Plate* IV., *Miscellany*, represent the usual modes of drawing designs for the species of ornamented cloth most commonly made in Great Britain. Different ways of effecting ornaments in the loom are practised, according to the fabric of the cloth, and the purpose to which it is to be applied. In the lighter manufactures of the silk, lawn, and muslin trades, now chiefly used as ornamental parts of female dress, the fabric is generally so flimsy, that, when ornamented in the loom, the figures, in order to have any show, must be composed of yarn, much coarser than that which forms the ground or fabric of the cloth, and this yarn is sometimes dyed of different colours. Being most convenient in general, and the patterns more easily changed, the weft, or woof, is most frequently used for this purpose. *Figures* 1 and 2, are representations of this kind of work. In *fig.* 1, every square of the design-paper is supposed to represent one thread both of warp and woof. In *fig.* 2, it is supposed to represent two. For the application of these designs to the purposes of mounting looms, see the article Draught and *Cording*.

In the heavier branches of the manufacture of cloth, ornaments are effected without any alteration in the fineness of either warp or woof, and most frequently without any change of colour. The *figs.* 3 and 5, refer to these kinds of work, and the squares in each of these may be supposed to represent any number of threads from three to eight, according to the fineness of the cloth, and labour bestowed in ornamenting it. *Fig.* 4, is also a kind of ornamented cloth of the dimity kind of a stout fabric. Each square upon the design represents one thread. For the application of these, see the respective articles Diaper, Dimity, Dornock, and Draw-Loom, especially the last.

When designs are drawn upon paper, the distance of the lines is generally so much more than the diameters of the threads which they represent, that the figure upon the cloth will often be very different both in size and appearance from the design. To calculate this accurately is an important part of the business of a skilful manufacturer. The rules, therefore, for this, with references to the plate, will be found in the respective articles to which they refer.

Some general remarks upon the principle of designing ornaments upon cloth, and upon the analogy which subsists between the figure of any flower or pattern, when drawn upon plain paper, when reduced to the design-paper, and when woven into the cloth, may, however, be useful to those who possess an adequate knowledge of the art of manufacturing plain cloth, but who are not equally conversant with the various branches of ornamental weaving.

When an oblique or curvilineal figure is drawn or painted, either upon canvas, paper, or any other substance, no impediment exists to prevent the artist from drawing every oblique straight line at whatever angle of obliquity he chuses, nor from forming whatever curves will add to the beauty of the picture. But, when an imitation of this is to be transferred to design-paper, and from thence to cloth, the same facilities do not exist, and the utmost which the most skilful weaver can effect is only the nearest possible approximation to the original from which he copies. Every person at all acquainted with weaving knows, that the threads of warp are stretched in the loom, forming straight lines parallel to each other, and that these threads are intersected by the woof at right angles. No oblique pattern can, therefore, be formed in the loom, except by varying the point in the warp, where the intersection showing the pattern appears, and every change of this point must be at least equal to the diameter of one thread. Now, if we suppose that there are equal quantities of warp and woof in a web, and that a shift of one thread of warp is made, to the right or left, every time that a thread of woof is passed across, the diagonal line produced will form invariably an angle of 45° both with warp and woof. The diagonal here, then, is produced by the resolution of two equal forces, acting at right angles to each other. But an obliquity, confined invariably to an angle of 45°, would produce a very limited range of patterns indeed. *Figs.* 1 and 2, are specimens of such as may be effected by it. It becomes, therefore, necessary, in more extensive designs, to vary the obliquity of the angles frequently, and this can only be done in two ways.

1st. By shifting the point of intersection over more than one thread of warp, which will render the angle formed by the diagonal line and warp greater, and that by the diagonal and the woof less than 45°, or

2d. By inserting more than one thread of woof without shifting the point of intersection, the effect of which will be exactly the converse of the former.

It is to be observed, that by the diagonal line is only meant the apparent line which is presented to the eye; for as the shifts are at right angles, each will form either a square or parallelogram, the true diagonal of which is intended to be represented, and the means used are therefore only approximations to this.

When the design (*fig.* 5.) is examined, as all the squares forming the flower are black, whilst those which represent the ground are vacant, every shift, when minutely inspected, is evidently at right angles, although the general effect, when viewed at some distance, has the appearance of diagonal or curved lines. But, were this pattern woven upon a fine cloth, the diameters of the threads would be so much less than the measures of the squares which represent them upon the paper, that the angular corners which give the edges of the flower the appearance of being dented, would totally disappear, unless very minutely inspected, and the flower upon the cloth would be much smaller than that upon the paper.

The following table of the angles, formed between the diagonals of parallelograms, whose sides are in the same ratio to each other as those upon the design-paper, has been calculated to assist in reducing the drawing of designs, as nearly as possible, to correct imitations of the drawings or paintings from which they are taken.

Table shewing by inspection the angles of obliquity formed by colouring the squares of design paper for weavers, both by the warp and woof, from 1 to 9 squares each way; the line of woof being taken as the base.

Squares of Warp.	Squares of Woof.								
	1	2	3	4	5	6	7	8	9
1	45°	27°	18°	14°	11°	9°	8°	7°	6°
2	63	45	34	27	22	18	16	14	13
3	72	56	45	37	31	27	23	21	18
4	76	63	53	45	39	34	30	27	24
5	79	68	59	51	45	40	36	32	29
6	81	72	63	56	50	45	41	37	34
7	82	74	67	60	54	49	45	41	38
8	83	76	69	63	58	53	49	45	42
9	84	77	72	66	61	56	52	48	45

The angles may be continued down to 1° and up to 89°, as follows: By the warp the number of squares to be coloured for one square of woof will be for 85°, 11 squares; for 86°, 14 squares; for 87°, 19 squares; for 88°, 29 squares; and for 89°, 53 squares. And reversing the operation for the same numbers the angles will respectively be the complements of those quoted, *viz.* 11 squares 5°; 14 squares 4°; 19 squares 3°; 29 squares 2°; and 53 squares 1°.

To understand this table it is necessary to observe, that the left hand column from top to bottom contains the number of squares, coloured upon the design-paper, and forming the edge of the flower by the warp, or contained between one or more spaces from top to bottom of the paper. The cross columns at the top contain the same by the woof, or across the design, and the figures, where the one column crosses the other, give the angle which the diagonal of a parallelogram, whose sides are in the ratios of the two numbers to each other, would form with the base or cross lines. When the number of coloured squares each way is equal, the angle is always 45°, and in all others the angle formed by the cross squares is always the complement of the same number from top to bottom. The minutes have been thrown away, being unnecessary in practice, and the nearest degree, whether a little more or less, taken.

When a pattern is to be reduced from a common drawing to a design for weaving, this table may be of considerable use; for if a cross line be drawn upon the original, the angles of obliquity may be taken with very considerable accuracy by a line of cords, or any of the usual mathematical processes, and a reference to the table will shew the number of squares which, when coloured, will produce the effect most nearly similar. Curve lines are formed merely by changing the angles of obliquity, as frequently as necessary. When it is desirable to make a smooth uniform line, it is always best to shift only one square at a time, and make the shifts more frequent; for when many are shifted, the square corners will be always too apparent; but where a rough edge is wanted, these may be resorted to.

The calculation of the size of the flower upon the cloth, compared with that upon the paper, is merely a case of simple proportion. In order to calculate correctly, the greatest number of squares coloured from right to left, and from top to bottom, must be counted, and the size of the flower each way measured; for design-paper is ruled to many different scales. The number of the reed, or, which is the same thing, the number of warp-threads in a given breadth, is then to be ascertained, and also how many threads are represented by each square. These points being fixed, the ratio of the one to the other will be readily found. A single example, taken from the damask flower, (*fig.* 5.) will illustrate this.

The squares coloured from right to left, counting from either extremity, are 107, and the measure is $5\frac{1}{8}$ inches.

From top to bottom the squares are 113, and the measure $5\frac{3}{8}$ nearly.

Let it be supposed that this pattern is to be wrought upon what is called a five leaf damask, containing 2400 threads in the compass of 37 inches. Every square will then represent five threads either way; and the threads contained in the warp of one flower will be 535.

Then as 2400 : 37 :: 535 : 8.2479, or nearly $8\frac{1}{4}$ inches. The flower, therefore, upon this scale, will be $3\frac{1}{8}$ inches broader upon the cloth than upon the paper, and the excess of length will be found by a similar proportion.

But were the same flower to be wrought as a spot, only two threads would be represented by each square, and the number of warp-threads would be 214 in each flower. Suppose then the muslin to be figured, to contain 3200 threads in 37 inches, the proportion would be

As 3200 : 37 :: 214 : 2.474, or nearly $2\frac{1}{2}$ inches. In this case the same flower, on the cloth, would be less than one-half of its breadth on the paper. The great disproportion in the size of the two flowers depends partly upon the difference in the number of threads represented by one square, and partly by the fineness or set of the webs. In the first, the ratio of decrement is *directly* as 2 to 5; in the second, *inversely* as 12 to 16.

When looms are mounted to work fanciful patterns, if the range is not too extensive, heddles are used, which are moved by levers or heddles attached to them below by cords, and which are pressed down by the weaver's feet. When the range of pattern becomes too extensive to render this mounting convenient, another apparatus is adopted, which will be found in the articles Diaper, Mounting, and the most extensive in that of Draw-loom. The more common mountings belong to the article Draught and *Cording*.

Dipping

DIPPING, in *Calico-Printing*, a procefs ufed in dyeing blue, in which the cloth is immerfed or dipped either in a folution of indigo, or of fome fubftance capable of acting on indigo previoufly applied to the cloth.

The peculiar nature of indigo unfits it for the purpofes of dyeing by the ordinary operations of the art. It confifts, as we fhall have occafion to fhew more fully hereafter, of a peculiar vegetable bafis united to a portion of oxygen, to which it owes its colour and infolubility. When deprived of this oxygen, by fubftances whofe affinity for it are greater, it becomes foluble in the alkalies and alkaline earths, and in

this state readily contracts an union with animal or vegetable stuffs. On this property of the alkalies to dissolve deoxygenated indigo, are founded two processes for dipping or dyeing blue, which form the subject of the present article. The first consists in immersing the cloth in an alkaline solution of indigo, and is employed in dyeing those goods, the ground of which is intended for blue or green. The parts meant to remain white, or which have already received some other colours, being covered with a reserve or paste, to protect them from the effect of the dye.

This process is very ancient.

The second is employed in dyeing those goods intended to exhibit a design or pattern in one or more shades of blue, upon a white ground, and is called "China blue," or generally upon the continent, English blue, the process having originated with the calico-printers of this country.

From time immemorial the nations of the east appear to have possessed a mode of dyeing silk handkerchiefs, and other articles of dress, by a rude but simple process, which is practised at this day, and has been adopted, and continues in use, in almost every part of Europe. It consists in tying knots with great address and nicety on the silk in such a manner, that when dyed, the parts enclosed within the knot remain untouched, displaying a ground of red, blue, or any other colour, variously, and oftentimes not inelegantly diversified with flowers of white or yellow, according to the primitive colour of the silk. This mode of dyeing handkerchiefs was introduced by the Saracens into Spain, where it is now practised to a very considerable extent. This, in all probability, was the first rude essay or attempt to imitate the printed linens of Egypt, and was succeeded by the mode now practised in India, of covering with a composition of wax and other ingredients, the parts intended to remain white. Hence we may date the origin of blue dipping, and though the process, as may be supposed, has been considerably improved since its introduction into Europe, yet the ancient practice is still in use; and wax printing is often employed with considerable advantage in the production of particular combinations of dark and light blue, which could not readily be obtained by any other process.

Of the Indigo Vat, and the Process of common blue Dipping.

The solution of indigo for blue dipping, is made in large oblong vessels of wood, stone, or other materials, to which the name of vats is given. Those which are made of wood require to be very accurately joined, and well secured with bolts and straps of iron; otherwise great loss may arise from the constant leakage, to which, without great precaution, they are subject. In general they are lined with lead, and though the expence in the first instance is four times that of wood, they are eventually much cheaper. They need fewer repairs, and afford absolute security against all loss by leakage, which, in a drug so costly as indigo, is a consideration of great importance. Stone vats have been tried in some places. At Rouen, according to Berthollet, they are constructed of a kind of flint-stone, well secured both outside and inside with a fine cement: and Pileur d'Appligny mentions some he had seen composed of large stone slabs screwed together at the corners, and the joints of which were covered with a kind of mastic varnish. Economy is the chief aim in all these various constructions, as it matters little what the vat is composed of, provided it will hold the dye; and those, in fact, are the cheapest, whatever they have cost, that suffer the least to escape.

The size of the vat varies considerably in different dye-houses, according to the nature and extent of the establishment, and the kind of work they are intended for. Four feet wide, six feet long, and six or seven feet deep, are the dimensions of a well-proportioned vat, calculated for two pieces of calico, or 56 yards of cloth on a frame. Much smaller than the size here given are in use for frames of single pieces, and vats of still larger dimensions are employed by some, whose work and cloth require them one or two feet deeper.

The vats are all sunk in the earth, down to a level, or nearly so, with the floor of the dye-house. In some few old establishments, they stand two feet, or thereabouts, above the floor, as is universally the case on the continent. In this case, the frames are hoisted in and out by a pulley suspended over the vat, a most awkward and inconvenient practice, which is avoided by sinking them to the level of the floor. The frames are lifted out with ease by the hand, by two men or boys, one at each end, and in a range of six or eight vats, the frames are hoisted out and re-entered in half the time, and with half the trouble, required to manage the pulleys.

The number of vats necessary in a well arranged dye-house must depend greatly on the nature and size of the establishment. Eight of the size already given, ranged in one line side by side, form a good series: double or treble that number may be required, but with fewer, a dyer, whose quantity of work is limited, yet various, will find much inconvenience, especially when by long working the dregs or grounds have so accumulated as to require a repose of 24 hours at least, after raking up before the vats are fit for work again. It is on this account that deep vats are preferable to shallow ones; the mud subsides in them much sooner, and they require cleaning out and emptying less frequently.

The nature of the indigo vat is such, that the indigo is revived and precipitated from it whenever it comes in contact with the air. On this account, it is impossible to dye a piece evenly by winching or working it in the dye liquor, as in other colours. Those parts of the piece which had been most exposed, and on which, of course, most indigo had been precipitated, would exhibit deeper shades than those which had been less. The reserve, or paste, also, for white, when such had been applied, would be disturbed and washed off by the usual manipulations of dyeing.

On these accounts it is necessary to hook the pieces on a frame in such a manner, that when immersed in the vat, or taken out, the folds shall not touch each other. The frames are of wood, the length and width nearly of the vat, and of a depth sufficient for the width of the goods. The horizontal side-rails at the bottom are fixed, and form the base of the frame, and are furnished with small tenter hooks of copper an inch and a half, or two inches asunder, to which the edge or selvedge of the piece is attached. The upper rails, which are also furnished with hooks, slide in a groove cut in the upright or corner posts, and may be adjusted to the width of any kind of cloth, and are retained in their place by a peg or pin. The piece is hooked in folds from side to side, and so evenly and tightly stretched, that when immersed in the vat every part is equally and alike exposed to the dye, and no one fold can touch another. The number of dips is regulated by the shade of blue required, and when finished, the goods are taken off the hooks and subjected to the ordinary operations of washing, rinsing, &c. &c. The solution of indigo, which, as well as the vessel that contains it, is generally called "blue vat" by the dyers, is made with lime and copperas, and in some cases with the addition of a small quantity of potash. In the due proportion of all the ingredients of this solution, and in the treatment of the vat, both during, and after working, consist the chief art of "blue dipping," in the management of which, however, there is less difficulty than in any other branch of blue dyeing

whatever. The theory is so simple, and the practice, to those acquainted with the theory, so very obvious, that with common care and observation it is scarcely possible to err.

Indigo, as we have just before observed, is insoluble in the alkalies and alkaline earths, till deprived of its oxygen. Copperas is employed for this purpose in the vats we are speaking of, and orpiment in others, and in the pencil blue; both these substances having a stronger affinity for oxygen than the base of the indigo. On adding together, therefore, indigo, copperas, and lime, in suitable proportions, the lime in the first instance decomposes the copperas, and precipitates from it the oxyd of iron: this acts on the indigo, deoxygenates it, and renders it soluble in the lime, which, if in sufficient quantity, immediately dissolves it. The oxyd of iron, which has served to deprive the indigo of its oxygen, the sulphate of lime formed by the union of the lime with the acid of the copperas, and any lime in excess or more than necessary to effect the decomposition of the copperas, and the solution of the deoxygenated indigo, all precipitate to the bottom of the vat, and there remains in solution only lime and the base of indigo. There are few dyers and calico-printers who do not imagine that the solution of indigo consists of all the substances that have been used in its formation, and that the vat actually holds in solution indigo, copperas, and lime. They are not aware that solutions of these two latter substances are incompatible; they cannot exist together, one or other must predominate, as a very simple experiment will shew: Mix clear lime water, and copperas water together, and an instant precipitation will take place. As long as any copperas remains in solution, every successive addition of lime water will cause a fresh precipitate, which consists of oxyd of iron, and sulphate of lime, formed by the union of the lime with the acid of the copperas. None of the lime remains in solution. The precipitation ceases only when the whole of the copperas is decomposed, that is, when there is no longer any acid to form an insoluble salt with the lime. The solution will then be found to consist of lime water only. To those in the least acquainted with the principles of chemistry, these observations may appear minute and trifling, but to those ignorant of these simple facts (and the majority of these interested in the subject of the present article are ignorant of them,) the constitution of the blue vat must be wholly unknown, and its management, of course, exposed to all those chances of failure and derangement which must necessarily attend even long experience, when unaccompanied with clear and accurate ideas of the nature and properties of the different substances employed.

The proportions of indigo, copperas, and lime, necessary to form a blue vat, depend both on the quality of the indigo, and on the strength of the solution required. The quality of indigo varies greatly, some kinds, as the fine Spanish and East India, containing twice, and even thrice, as much colouring matter as the coarser kinds. In general from two to five pounds of good indigo to every hundred gallons of water, are sufficient to form vats for most purposes. They are sometimes, but rarely, required stronger; 40 pounds in a vat holding 800 gallons, will produce a solution of sufficient intensity to give a black nearly, at four or five immersions.

The finer the quality of the indigo, and the greater the proportion of copperas and lime, necessary to effect its solution. In general, however, one of indigo, two of copperas, and two of lime, are considered as the best proportions, and as such they are given by Berthollet, who, to profound chemical science, unites considerable practical knowledge, and the best information concerning the processes of the dyers and calico-printers of France.

The indigo is previously ground in a mill with water, till it is reduced to a smooth paste of the consistence of cream. In its ordinary state of aggregation, it is scarcely, if at all, attacked by copperas and lime; all therefore that has escaped the action of the mill, and is put into the vat in a lumpy or imperfectly ground state, may be considered as totally lost. Every precaution therefore should be employed to guard against this, and when by rubbing it between the fingers, or on a pane of glass, it appears fine and smooth, and free from small hard, gritty particles, it may be removed from the mill, mixed up with four or five times its bulk of water, and poured through a fine sieve into the vat. Any lumps which may have escaped grinding are thus retained, and may be returned into the mill with fresh indigo.

The vat having received its charge of indigo, and been filled up with clean water, the copperas is next added. It is best and most speedily dissolved by suspending it in a wicker basket at the surface of the vat; it is sometimes thrown in, and will, in that case, when it is in large lumps, oftentimes lie undissolved at the bottom of the vat for weeks, in spite of frequent and even daily stirring. When the whole is dissolved, the lime is added, and the vat well raked up, till all its contents are intimately mixed, the lime dissolved, and the copperas decomposed. The action of oxyd of iron upon indigo requires time, and also repose; after the first raking, which should be continued during half an hour at least, it is best to suffer the vat to remain two or three hours undisturbed; the indigo and oxyd of iron fall down to the bottom, and are thus brought more within the sphere of chemical action, than when floating in the whole mass of water in the vat.

The choice of copperas is not a matter of indifference, as on its peculiar state depends its fitness or not for deoxygenating indigo. Sulphate of iron exists in two states dependent on the quantity of oxygen combined with its oxyd. At its minimum of oxydation, it forms a green solution, and when crystallized, a green salt, the green vitriol, or copperas of commerce; at its maximum, or second state of oxydation, it forms an orange-coloured, uncrystallizable solution possessing very different properties from the former.

The green solution is distinguished by its great avidity for oxygen, and its disposition to pass to the orange, or fully oxygenated state. It is this affinity for oxygen that fits it for the solution of indigo. The copperas of commerce is however not unfrequently a mixture of the two salts or oxyds a portion of it either having acquired oxygen, whilst in a state of solution before crystallization, or more frequently perhaps by too great exposure to the air afterwards.

In this latter case its surface is covered with a reddish orange rust, and a portion of the salt is rendered useless for the blue vat having already acquired its maximum of oxygen. The chief difference in the quality of copperas, is however in the more or less perfect saturation of the acid, forming two distinct salts, which were known and distinguished by manufacturers long before chemists were acquainted with their existence. The first, and least esteemed, is a pale emerald green, and contains a great excess of acid; the other which is more fully saturated with iron, is a deep full green and is universally preferred, especially for indigo and China blue vats. Some calico-printers imagine that the reddish coloured copperas is the best, or, as they say, the *strongest*, a prejudice which the manufacturer very easily accommodates by sprinkling a little fine sifted quick lime over the surface which soon covers it with a coat of orange rust.

The lime used for the indigo vat should be quick. Falle

lime, when not too old, and too long expofed to the air, is the beft. It fhould be well fifted, and freed from ftones and lumps.

After two or three hours repofe, the vat fhould be again well raked. It will now exhibit figns of incipient folution; inftead of black, it will appear of a dark bottle green, and the furface will break into marbled veins of blue. Thefe appearances will increafe each time the vat is raked, which fhould be three or four times a day during two days. At each time the colour of the vat will brighten, and get paler, the marbled or veined appearance become more marked and ftrong, and when the folution is compleat, and ready for working, the colour, when raked up, will be a yellowifh green. After a repofe of ten or twelve hours, to allow the dregs time to fubfide, the vat is ready for work.

It is the practice of fome dyers to add potafh in equal quantity with indigo to the vat. The only advantage arifing from this, is greater concentration of the folution than can be obtained by lime alone; but this is feldom required, and never, indeed, for the purpofes of calico-printing; on the other hand, if potafh be added to a vat containing little indigo, and calculated only for the paler fhades of blue, the colour it will produce is lefs intenfe, than when lime alone is ufed, and the hue not at all improved.

It was formerly the practice to grind the indigo with a folution of cauftic potafh, and boil it in a ftrong lye, before adding lime and copperas, and pouring it into the vat. A great deal of trouble, and no advantage whatever attends this procefs, which is now univerfally difcarded, except by thofe who regard all improvements as innovations.

Of the management of the vats both during work and after, we fhall have occafion to fpeak whilft treating of particular kinds of work; which, after the preceding general view of the nature of the proceffes, and the mode of preparing the indigo vats, we fhall now proceed to.

Of dark Blue ground, and white.

Dark blue grounds, with fpots or figures of white, were amongft the firft attempts at calico-printing in the Eaft, and were produced, as we have before remarked, firft, by tying knots on the part intended to remain white, and afterwards by covering them with a compofition of wax. This procefs was fubject to great inconveniencies, arifing from the unmanageable nature of the compofition, which required keeping fluid by heat during the time it was applied, and could only be ufed in certain plain figures, fuch as round fpots, ovals, &c. The defigns were of courfe rude and fimilar, little variety being practicable where lines, ftalks, leaves, or any object more figured than a fpot or oval, could not be obtained.

At what time the pafte or referve now in general ufe was introduced, is not known; we are indebted for it to the continent, from whence, indeed, our firft knowledge of calico-printing was derived. Though the formulæ for this pafte differ much, every blue dyer almoft, preparing it in a mode peculiar to himfelf, yet they are all effentially the fame, a folution of copper of one kind or another being the principal ingredient.

If a folution of fulphate, acetate, nitrate, or indeed any foluble falt of copper, properly thickened for printing, be applied to cloth, and when dry, immerfed in the blue vat, the part fo covered will refift the action of the dye, and remain white. This does not arife from the mere mechanical refiftance of the pafte, which prevents the folution of indigo from entering the fibres of the cloth, but from the chemical action of the oxyd of copper, which imparting oxygen to the indigo, reftores it to its former blue ftate, in which it poffeffes neither folubility in lime, nor difpofition to unite with the cloth. This effect of the oxyd of copper may be rendered very apparent, by pouring a folution of it into a folution of indigo, which is generally of a yellowifh green, or when viewed by tranfmitted light, of the colour of fmall beer. The inftant the two folutions are mixed, the indigo is revived, and precipitated in its original blue ftate, having acquired from the copper that principle of which it had been deprived by the folution of fulphate of iron. Every pafte, or referve, therefore, for dark blue grounds, muft neceffarily contain oxyd of copper; we give the following formulæ as moft approved of any in ufe.

I. To 1 gallon of water add,
4 lbs. of fulphate of copper,
12 lbs. of pipe clay.

Boil the whole up into a thick pafte, ftrain through a cloth, and add to it half a pint of fulphuric acid, and five pints of thick gum water. Mix all well together, and ftrain again before printing.

II. To 1 gallon of vinegar add,
1½ lbs. of verdigreafe,
3 lbs. of fulphate of copper.

Diffolve them over the fire, and thicken with 12 lbs. of pipe clay, finely ground.

If the pafte is not fine and fmooth, run it through the mill, and add to it, whilft hot, 8 ozs. of linfeed oil, and two quarts of thick gum water. Strain it carefully through a cloth before printing.

III. To 1 gallon of water add,
2 lbs. of verdigreafe,
3 lbs. of fulphate of copper,
3 lbs. of nitrous acid,
15 lbs. of pipe clay.

Boil them well in a copper pan, and, if neceffary, grind them fmooth, and add three quarts of thick gum water. Strain the whole very well before printing.

The firft of thefe formulæ contains fulphate of copper only, the folubility of which is increafed by the addition of a little fulphuric acid, which prevents the cryftallization of the pafte. The fecond, which is ftronger, contains alfo acetate of copper, and the third, in addition to both thefe falts, contains a portion of nitrate of copper formed by the action of the nitrous acid on the verdigreafe. This is a very powerful pafte, and capable of refifting the vat a long time, and forming a white upon a ground nearly black.

The pipe clay ufed in thickening, is not merely ufeful in giving due confiftence and body to the pafte, fo as to render it eafily workable, but is very efficacious in refifting the dye; the fame folution, thickened with gum only, will fcarcely bear three immerfions, but with the allowance of pipe clay here directed, will ftand ten or twelve. No more gum, indeed, fhould be added than is juft fufficient to break the adhefive nature of the pipe clay, and prevent it clogging up the print or block.

In working this pafte the mall, or mallet, fhould be ufed very lightly, or not at all, if the pattern will admit of it. A gentle tap with the hand, fo as to leave the pafte wholly on the furface of the cloth, will produce the beft work.

The cloth may be dipped an hour or two after printing, if required, but the whites are feldom fo good as when kept three or four days. The pafte gets hard and firm, part of the acid evaporates, and the folution of copper becomes more intimately incorporated with the cloth.

Dark blues, in general, require from five to ten dips, or immerfions, according to the fhade of blue required, or the ftrength of the vats employed.

If the vats are ftrong, five, or at moft fix dips, will give a

very dark blue, almost black, the intensity of which will be little increased by further dipping; the labour is greatly abridged by employing strong vats, but the whites are liable to great injury, as the solution of indigo, when concentrated, acts very powerfully on the paste. On this account the first vat should invariably be the weakest of the series, and never stronger than is sufficient to produce a full strong blue at seven, or even eight immersions. The second and third vats may be stronger, and so on to the last, which may be the strongest of all. Dark blues may be dipped and finished in the same vat, but it is more convenient to pass them in succession through a series disposed in a line in the manner we have before described.

When the piece is well hooked, and the frame ready, the vat must be well skimmed before the piece is entered. The surface of a blue vat is always covered with a film of revived indigo, more or less thick, according to the strength of the vat. This film it is necessary to remove before the frame is immersed, otherwise the revived indigo, which is no longer in solution, attaches itself, and adheres to the cloth in patches, producing unevenness in the dye, especially in the first vat. When skimmed, the surface of the vat is dark green, but the blue film re-appears in a few minutes; it should not be removed, therefore, till the frame is ready for immersion.

In five or six minutes the cloth has fully imbibed the dye, and little advantage is gained in general by keeping it longer in the vat. The frame is then lifted out, and placed slantwise in such a manner, that all the liquor which drains from the piece falls down into the vat again. When taken out, the cloth appears of a pale yellowish green, if the vat is weak, but if strong, more inclining to amber. This colour gradually changes, as the indigo, by absorbing oxygen from the atmosphere, becomes revived, and in five minutes the cloth appears uniformly blue; it is then ready for another immersion. Six minutes *in*, and six minutes *out*, is a good general rule for dipping dark blues, as the cloth will in that time have acquired the full effect of the vat, and *the green will also go off* in little more than five minutes, though the vat be very strong. The bottom edge of the piece retains the green hue the longest, because it is longest in draining from the liquor; care must be taken, therefore, never to immerse a piece till the bottom edge has been examined, and found perfectly ready for the dip. The consequence of entering a piece into the vat whilst the bottom edge is green, is, as might be supposed, that the edge will be the palest, the indigo not having been revived and precipitated upon it equally with the rest of the piece.

In dipping dark blues, the first dip is the most important; and if it fails, the work is inevitably ruined. First, if the vat be too strong, the whites will never be clear and sharp; secondly, if for want of due preparation the cloth does not uniformly receive the dye, the goods will scarcely ever be even when finished. Thirdly, if either from the paste being too strong, or the vat too weak, or not in proper order, the impression starts, or runs at the first immersion, the ground is sure to be freckled and uneven, and the whites bad.

Against the first source of error, the knowledge of the fact ought to be a sufficient guard; but if unavoidably it should happen that the leading vat is too strong, there is no other remedy than shortening the time of the dip, and keeping the frame in four or five minutes in lieu of six, till the vat becomes reduced in strength.

Imperfect bleaching, accidental impurity in the cloth, and long and partial exposure to heat and air, are amongst the causes which contribute most to prevent the cloth from receiving the blue dye.

It is the practice with many printers to give the cloth intended for this purpose an extra preparation, either by boiling in a lye of potash, or a solution of common salt. If the regular bleaching has been perfect, the first is wholly unnecessary, and the second absolutely useless.

Cloth that has been well bleached may, by long keeping, and partial exposure to the air, dust, and other accidental impurities, become so unfit for dipping, as to require some extra preparation. In this case the modes we have spoken of may be useful inasmuch as washing, soaking in hot water, squeezing, and the other attendant operations are useful, but clean, well bleached, and recently bleached cloth has no need of any such preparation.

If the paste be too strong, that is, if it contains too much sulphate, acetate, or nitrate of copper, it is liable to start or run in the first vat, especially when laid on in large bodies. This evil, if not too great, may be remedied by gently moving the frame up and down during the first two or three minutes after it is entered. It may also arise from the vat being too weak, and consequently containing too little lime in solution, and may sometimes be remedied by the addition of more lime. If in spite, however, of the motion of the frame, the addition of more lime, or of greater strength to the vat, the paste still continues to run, it is a sign the solution of copper is too strong, and the quantity must immediately be diminished.

When the green is gone off after the first dip, the frame is then moved on, and dipped in the second vat, taking care to skim it well before the piece is entered. In this way, after each immersion, the frame is moved on to the next succeeding vat, till it has received the number of dips required. This, as we have before observed, depends on the strength of the vat, and the shade of blue wanted; but as, during the process of dipping, the vats continually get weaker, the goods, after a certain time, will require an additional immersion, or even two or three, to get them up to the strength of the first pieces that were entered.

The strength of a blue vat is not exhausted in the same manner as the weld or madder bath, by the abstraction of the colouring matter from the solution, by the superior affinity of the mordant on the stuff. When a piece of cloth is immersed in the indigo vat, it becomes penetrated in five or six minutes compleatly with the dye, and will gain nothing, by being suffered to remain longer than is necessary for this purpose. When taken out, it carries with it no more indigo than is contained in that quantity of solution which it has imbibed, and carries out of the vat. But the instant the frame is lifted out, the liquor begins to drain from it back again into the vat, and pours down in small streams, thus exposing the solution compleatly to the atmospheric air. The indigo is in consequence revived and precipitated, so that the liquor which drains from the piece, and falls down into the vat, is for the purpose of dyeing, no better than so much water. Every frame that is entered thus effecting the precipitation of the colouring from matter two, three, or four gallons of the solution, the vat, especially the leading one, soon becomes reduced in strength. The second, third, and successive vats, are weakened in the same manner, and also by the exhausted liquor of the pieces, which at every dip after the first, is exchanged, as it were, for the fresh and strong solution of the vat it is immersed in.

When the goods have received the last dip, and have acquired their full shade of colour, they are taken off the hooks, and well winched in clean water; they are then, by the successive operations of washing and hot watering, repeated as occasion may require, freed from the paste, and rendered as clean as possible before going into the sours.

Souring is neceſſary to free them from the laſt remains of the paſte, and give a brightneſs and finiſh to the whites. A ſolution of ſulphuric acid, weak enough to be borne in the mouth without inconvenience, is ſufficient to diſſolve what oxyd of copper is left in the cloth after good cleaning. The goods are immerſed in this ten or fifteen minutes, after which they are well waſhed and hot watered, and when dry are finiſhed, or ready for any ſucceeding operations. The excellence of this kind of work depends on the clearneſs and purity of the white, and on the fulneſs and evenneſs of the blue. The directions we have given are, with ordinary care and obſervation, ſufficient for the attainment of this.

When the vats have become exhauſted by working, they muſt be *refreſhed.* If a vat contains a tolerable charge of indigo, copperas, and lime, and has been worked only once, raking up alone will be ſufficient to put it in a ſtate for working again. When again exhauſted, copperas and lime muſt be added to diſſolve the revived indigo. The quantity muſt depend upon the ſize of the vat, and the ſuppoſed quantity of indigo which it contains. From 20 to 40 lbs. of copperas, and three-fourths of that quantity of quick lime, may be added at once to a vat of 1000 gallons, or thereabouts, and ſome idea may be formed of the effect which this ſhould produce, by recollecting that one pound of indigo requires for ſolution about two pounds of ſulphate of iron. It is proper always to have an exceſs of quick lime in the vat, but it is wholly unneceſſary to make thoſe frequent additions of lime without any thing elſe, which is the practice of many blue dyers. It ſerves no other purpoſe than to fill the vat ſpeedily with dregs, which ought to be avoided as much as poſſible, as when they are accumulated to a certain pitch, it is neceſſary either to take them out, or ſuffer the vat to repoſe from 36 to 48 hours before it is fit for work after raking.

If equal quantities of copperas and lime have been uſed when the vat was formed at firſt, and three parts lime added for every four of copperas afterwards, any other addition of lime is wholly uſeleſs. Some idea may be formed of the ſtate and condition of a vat, by obſerving its appearance when raked up. In general, if it looks dark green or black, it may be preſumed it contains a quantity of revived or undiſſolved indigo, and copperas and lime are therefore neceſſary; this blackiſh appearance may nevertheleſs be occaſioned by a very great exceſs of copperas, or ſulphate of iron, the oxyd of which, when recently precipitated by lime, is dark green; as this, however, could ariſe only through great ignorance, or accident, it is not often likely to be the caſe, as the quantity of copperas required to produce this effect muſt be very great indeed.

When a vat rakes up yellow, or very pale yellowiſh green, it is ſuppoſed by ſome to contain too much copperas, and muſt be corrected by the addition of more lime. It is hardly correct, as we have before obſerved, to ſay a vat contains an exceſs of copperas, ſince this ſalt cannot exiſt in ſolution with lime. A vat may want lime, and in this caſe it will be very weak, of a pale yellowiſh green, produce a very feeble blue, and the paſte will invariably *creep*, to uſe the dyers' phraſe, or in other words, will run, and loſe the ſharpneſs and ſmartneſs of the impreſſion, the moment it is entered in the vat. This may be the caſe at the time the vat contains a quantity of revived indigo alſo, and rakes up black, ſo that no certain concluſion can be drawn from the yellowiſh appearance aforeſaid.

If a vat be weak, the froth which forms at the top during raking, is pale ſky blue; the ſurface does not ſpeedily break into marble veins, nor is it ſoon covered with a blue film. A ſtrong well conditioned vat, on the contrary, when raked up, becomes covered directly with a permanent and copious froth, the colour of which varies from a deep blue, when the vat is of ordinary ſtrength, to a bright copper colour, which is always characteriſtic of a very ſtrong ſolution, and the ſurface, when ſkimmed, is in an inſtant covered with a thick film of revived indigo. This film, and the deep blue and copper coloured froth, is the beſt and pureſt of the indigo, and is called the *flower of the indigo* by the old dyers. In ſkimming, great care muſt be taken that this is carefully preſerved, and returned again into the vats at the time they are refreſhed.

When a vat becomes ſo exhauſted that further additions of lime and copperas have no effect in increaſing the ſtrength, freſh indigo muſt be added, with the proportions of lime and copperas before indicated.

If a vat remains ſeveral weeks unworked and without raking, it will abſorb oxygen enough from the air to precipitate the indigo from the ſolution, ſo that, to the depth of 10 or 12 inches from the ſurface, it will conſiſt of lime-water only, and muſt be well raked up before it is worked.

When the dregs have accumulated ſo much as to prevent the vat from clearing in 24, or at moſt 36 hours, and when the frame begins to touch the mud during work, it is time then to empty it out, taking care to doſe the vat well with lime and copperas, ſo as to get out all the indigo before the dregs are thrown away as exhauſted.

Of Pale Blue.

Pale blues are, in general, produced at a ſingle dip; they require leſs indigo and labour than the preceding ſtyle of work, but more care and management to do them well. They are liable to be uneven and ſpotted in the ground, and the proper tone and ſhade of colour is a matter of great importance, and alſo of no ſmall difficulty.

We ſhall ſpeak firſt of pale blues and white, intended to be finiſhed up with after-colours or not.—The paſte for pale blue is preciſely ſimilar to that for the dark blue we have been treating of, except that it need not be ſo ſtrong. Two pounds of ſulphate of copper, diſſolved in a gallon of water, and thickened with pipe-clay and gum, in the manner of the three paſtes we have already given, will form a very good reſerve for pale blue. Any other ſolution of copper will be equally efficacious, but the ſulphate, as being the cheapeſt, may be conſidered as the beſt.

The preparation, or rather the condition of the cloth, is a matter of the greateſt importance in pale blue dipping. If imperfectly bleached, or ſtained or impregnated with any earthy or metallic ſubſtance that will obſtruct the entrance of the dye, the blue will infallibly be uneven. A difference in the quality of the cotton, in the fineneſs of the weft, or in the hardneſs of the twiſt, of which the cloth is made, will occaſion conſiderable variation in the ſhade of blue, and defeat every attempt, on the part of the workman, to do juſtice to his work. To guard as much as poſſible againſt this, the cloth, in the firſt place, ſhould be ſelected purpoſely, rejecting all thoſe pieces which ſhew unevenneſs in weaving, or variation in the quality of the materials.

The goods ſhould be in the beſt poſſible ſtate for printing; freſh from the bleach ground, carefully kept from duſt or dirt of any kind, and ſufficiently damp to make them take a ſtiff calendering. As ſoon after printing as convenient, they ſhould be removed from the warm ſhop to a cool ſituation, where they will not get parched and dry, and dipped at furtheſt the following day.

All theſe precautions, however, are inadequate to ſecure an even and level ground, without recourſe to the improved

method of dipping, for which we are indebted to the calico-printers of London.

This improvement, whether confidered with reference to the particular ftyle of work, of which we are now treating, or its application to other branches of blue dyeing, the moft important that has lately been introduced, confifts in dipping the goods in clear lime-water before they are entered in the blue vat.

If the piece becomes uniformly wet throughout, and fhews no ftreaks or patches of white, it may fafely be transferred to the blue vat as a piece that will take an even dye. If, however, after remaining five or fix minutes in the lime-vat, there are parts which are not compleatly wet, it muft be dipped five or fix minutes longer, and again taken out and examined. All thofe pieces which, after two, or, at moft, three immerfions, ftill refufe admiffion to the lime-water, are rejected as unfit for dipping, and the pafte being removed by fouring, are appropriated to fome other courfe of work to which they are better adapted.

The vat for pale blues is, in general, the fame as for the dark grounds, care being taken to felect one that will give the fhade of blue required. It is ufual to employ the old and nearly exhaufted vats for this purpofe, but the blue is never fo bright and lively as when frefh indigo, and that of the fineft quality, is employed.

The hue is greatly improved by fouring, a neceffary operation, to free the goods from the pafte, and ftill further, by winching them in a folution of white foap 10 or 15 minutes, at a heat of 120°.

Mr. Haufman obferves, that if the goods are plunged in a weak folution of fulphuric acid immediately on coming out of the vat, the blue is more lively and full than when previoufly rinfed and wafhed.

Mr. Chaptal employs for pale blue grounds without white, and for green grounds alfo, a vat compofed of indigo, potafh, lime, and orpiment. This folution, which is the fame precifely as the pencil-blue of the calico-printers, affords a much more delicate colour than that with lime and copperas, the caufe of which is not clearly underftood, though it moft probably arifes from the different degrees of deoxydation produced by the two fubftances.

This vat is formed by boiling 10lbs. of fine Spanifh indigo, 10lbs. of potafh, 20lbs. of quick-lime, and 5lbs. of orange orpiment, in about 30 gallons of water, and pouring it, when the folution is compleat, into the vat containing about 800 gallons of water, and 20 or 30lbs. of lime. When worked, it muft be raked up well the inftant before the frame is entered, and when exhaufted, refrefhed with additions of the fame folution.

If a piece of cloth, printed with the referve or pafte before defcribed, be dipped in this vat, the copper becomes precipitated and fixed by the fulphuretted hydrogen which it contains, and produces a brown ftain inftead of a white. It is poffible, however, with extraordinary care and management, to fucceed in obtaining good whites in this vat, and the following procefs may be employed with fuccefs, though it is ftill capable of further improvement.

Prepare a pafte by diffolving 2lbs. of fulphate of copper in one gallon of acetate of alumine, or the common aluminous mordant of the calico-printers, add to it 1lb. of nitrous acid, and 8lbs. of pipe-clay; boil well and ftrain it through a fine cloth, and when cold, add as much thick gum-water as is barely neceffary to give it the due degree of confiftence for working. In printing this pafte the mallet fhould never be ufed, a gentle tap with the hand, if the block is true and in good order, will leave the pafte, as it fhould be, wholly on the furface of the cloth. Dip fix or eight minutes in the lime-vat, and when taken out, fuffer the piece to drain two or three minutes before entering in the blue vat. The vat fhould be ftrong enough to produce the fhade required in two minutes, after which the frame fhould be withdrawn and plunged inftantly in a vat of clear water, and moved and agitated therein till the green goes off. When wafhed and foured, if the work has fucceeded, the white will be clear and prominent, and the blue the fineft that can be produced on cloth. It is remarkable, that a ftrong vat produces better whites than a weak one, on this account care muft be taken, that the folution be of a proper ftrength. The utmoft nicety is required in preferving the cloth for this vat from duft or dirt of any kind. Goods that have been long bleached, and not carefully fecluded from the air, are wholly unfit. They ought, in fact, to be taken frefh from the fours, for every, even the fmalleft particle of metallic fubftance that is in the cloth, when dipped in this vat, will produce a brown ftain, and if the cloth is uniformly tainted with it, entirely ruin the blue.

In dipping pale blue grounds, it is fometimes neceffary to protect colours that have been previoufly applied, from the effect of the blue, as red or yellow flowers for example, which would otherwife become purple and green. The folutions of copper cannot be employed for this purpofe, as they injure the colours, efpecially madder reds, or purples, very much, and are not wholly removed without fouring, an operation which goods of this defcription cannot be fubjected to.

The referve moft commonly ufed, is fimply a pafte of pipe-clay or Spanifh white, boiled to a proper confiftence, and mixed with an equal quantity of thick gum-water. This does not affect the colours upon which it is applied, and is eafily removed by hot water and wafhing; but as it oppofes merely a mechanical refiftance to the dye, and fails the moment it becomes foftened, it will not bear a dip of more than one minute or two. This is an inconvenience of great magnitude, when the pale blue ground is much expofed, and not covered with any kind of defign calculated to hide unevennefs in the dye. The following pafte is recommended and ufed, by fome, as capable of refifting much longer than the former:—

One pound of finely ground pipe clay,
Four ounces of gum-arabic,
Two ounces of fuet,
Two ounces of wax, and
One ounce of refin.

Boil all thefe ingredients together, in as much water as will form a pafte of fufficient confiftence not to run. This pafte can only be applied with the pencil, and in large maffes. It is removed with great eafe by hot water and wafhing, without any injury to the reds, or other colours it has covered.

The folutions of lead poffefs the property, though in a much fmaller degree than copper, of refifting the indigo vat, and may be ufed with advantage for pafting reds and other colours, which are but little injured by them. We have feen the following pafte ufed with great fuccefs:—

Diffolve two pounds of acetate of lead in a gallon of water, add two ounces of tallow, two of wax, and two of refin, and as much pipe-clay and gum as will make it of a proper thicknefs for printing or pencilling. This pafte will refift a dip of three or four minutes; it muft, however, be laid on in good bodies, and fucceeds better with the pencil than block.

In pale blue grounds, with black and white figures, &c. it is often neceffary to print both the black and the pafte

at the same time, to save the expence and trouble of aftergrounding. The black for this purpose is generally chemical black, for an account of which we must refer to the article COLOUR-*making*. The sulphate of copper paste is generally used, but as the goods cannot, on account of the black, be passed through the sours to free them from the oxyd of copper, which imparts a greenish hue to the white, it is better to employ the nitrate of copper, which is cleared by hot watering and washing much more compleatly.

If the patterns contain very large masses or bodies of black, the acetate of iron, or what the printers call black colour, must be used, increasing the strength to double that required for an ordinary black; so that when the goods are dipped, and as well cleaned as possible, by repeated washing, &c. they may be passed through water rendered slightly acidulous with nitrous, or what is still better, acetous acid, without materially impairing the strength of the mordant.

The white is compleatly freed from the oxyd of copper by this slight souring, and takes no stain in the dye copper, when the black is raised with sumac and logwood.

It is proper to observe, that the goods, before souring, should be compleatly freed from all superfluous paste, either of the black or white; and the iron, by repeated hot watering, at a temperature of 140°, oxygenated as highly as possible. In this state it is scarcely soluble, either in nitrous or acetous acids, and will bear weak solutions of them 15 or 20 minutes.

Of Resisting Mordants.

When a pale blue is intended to exhibit other colours on the ground, as red, pink, yellow, orange, &c. the paste or reserve is often mixed with a mordant capable of producing these colours in the dye copper.

The common paste alone will produce a yellow with weld, quercitron bark, fustic, &c. if the piece be simply rinsed and washed before dyeing.

In this case the oxyd of copper which remains in the cloth attracts the colouring matter, and though it is greatly inferior as a mordant, to the acetate of alumine, yet, with care and management, it is capable of producing, with weld, a pale and beautiful yellow. The only difficulty consists in getting the colour even, and this is best attained by employing those solutions of copper which are most soluble, and using them somewhat stronger than is merely necessary to resist the vat.

When dipped, the goods should be well rinsed in the river 15 or 20 minutes, and afterwards rinsed off in a copper of warm water, with a shovel full of cow-dung. Too much dung, or too great heat, will injure the yellow, the temperature should not exceed 100°, and after winching again in the river, they should be dyed at a heat considerably below this, if weld is used, and not exceeding 75 or 80 if dyed with bark.

Oxyd of copper, when dyed at a high temperature, invariably becomes dull, especially when bark or sumac are employed. With weld there is less risk of injuring the brightness of the yellow, but long continued heat impairs it greatly.

This mordant does not at all answer for reds; with madder it affords a dull wine-coloured dye, and with brazil, peachwood, and cochineal, dull, heavy colours, more inclining to pompadour or chocolate than red. When mixed, even in small proportions, with the common aluminous mordant, its effects are very visible, when dyed with any of the above-mentioned drugs.

It is nevertheless employed for deep full reds, upon pale blue ground, according to the following formula, which is excellent for a yellow or orange:—

Dissolve 2 lbs. of acetate of lead, and 2½ lbs. of alum, in a gallon of water; pour off the solution from the precipitate, and add 8 ozs. of sulphate of copper; thicken with 1½ lb. of starch, and 4 lbs. of fine pipe-clay. When cool, strain the paste through a cloth or sieve, and give the goods six days age before dipping. Dip three minutes in a well-conditioned vat, and transfer the frame from thence instantly to the water-vat.—Rinse off, and prepare for dyeing in the same manner as before directed.

The following formula is in use for resisting reds or yellows:—Dissolve in one gallon of warm water 3½ lbs. of acetate of lead, and 5 lbs of alum; thicken it (with the precipitate in) with the best Senegal gum, and add 2 ozs. of white arsenic, ground as fine as flour; 4 ozs. of common salt, and 4 ozs. of corrosive sublimate. Give the goods two or three days age before dipping, and keep them from three to five minutes in a good vat, or less, if you can get the shade of blue required. Plunge them in the water-vat the instant they are taken up, and rinse and finish as before.

Bark or weld drabs and olives, as they do not so soon shew any slight tinge of blue which may have penetrated the paste, may be simply thickened with good starch, and from 12 to 16 ozs. of suet per gallon, to enable them the better to resist the vat. If this should not suffice, from 2 to 4 ozs. of sulphate of copper may be added, but it must be observed, that this will change the hue of the drab, and make it more an olive. A little pipe-clay, not more than 2 lbs. per gallon, may be employed also with advantage. It is very efficacious in keeping out the dye, and, in so small a quantity, will not materially affect the fullness and evenness of the mordant.

Solutions of tin, more especially the nitro-muriatic, are employed by some calico-printers, in conjunction with the aluminous mordant, for resisting reds and yellows. They are not very powerful in keeping out the blue, and, with madder, afford but feeble colours: the yellow they produce is bright, but pale.

In general, those solutions which are most efficacious in resisting the vat, are the worst mordants, as those of copper for example; but as they will bear a long dip, and the evenness of the blue is thereby ensured, this advantage, in one colour, is considered as sufficient compensation for want of brilliancy in the other. The common aluminous mordant, thickened with gum and a little pipe-clay, or with starch and pipe-clay, forms infinitely the best mordant, and will resist the vat a few seconds, but not sufficiently long to make the work secure. The recent improvement in this kind of dipping, however, by the use of warm vats, has removed a great many difficulties, and enabled some calico-printers to produce work of very superior merit.

The great and the only advantage attending warm vats, is the celerity with which the dye penetrates the cloth; so that all the effect of a six minutes' dip in a cold vat, may, in a warm one, be obtained in the same number of seconds. The frame, in fact, is plunged in only for a moment, and instantly taken up; and, in this short space, the vat, however strong, has not time to penetrate the paste or mordant.

The vats may be variously heated, as best suits the nature of the establishment. Steam affords the most easy and efficacious means, and may either be thrown into the vat through a pipe and valves, in which case the steam itself is condensed in, and mingles with the solution of indigo, or the vat may be in part surrounded with a casing, into which the steam may be admitted, and give out its heat, without filling the vat with condensed water.

The first is the simplest and most economical mode; but it requires certain precautions which the other does not. In the first place, before the steam is admitted into it, the boiler should be *blown*, that is, compleatly emptied of air; for if it passes along with the steam into a vat, the indigo will be revived, and precipitated from the solution, and the vat rendered unfit for dipping. In the second place, if the vat, when cold, is only of the proper strength, the admission of so much steam, and consequently of condensed water, as will be necessary to raise it to the temperature required, will weaken it considerably; and lastly, some inconvenience may arise from this great accumulation of condensed water, unless due allowance be made before it is admitted, and care be taken never to turn it in when the vat is full.

The second mode is subject to none of these inconveniences. The vat can neither be weakened by air from the boiler, nor by condensed water, since the heat is transmitted wholly through the casing. The expence, however, is very considerable; still it is greatly preferable to the plan which some printers have adopted, of constructing cast iron vats, and heating them by furnaces built underneath.

The temperature at which they can be employed, varies according to the kind of work, and the power which the paste possesses of resisting a hot vat.

From 60 to 80° will be sufficient for most purposes, and a vat of tolerable strength will, at the latter temperature, produce a good blue in ten or fifteen seconds.

Of coloured Paste.

By mixing both colouring matter and mordant with the reserve, we obtain pastes which at the same time communicate colour to the cloth, and resist the blue; not only saving the necessity of dyeing, but enabling us to form combinations of colours, incompatible by any other process. This branch of blue dipping is still in its infancy, and little has yet been done towards its perfection. We shall therefore have little else to do in treating of this part of our subject, but to state the few facts on which it is founded, and suggest some hints for its future improvement.

If a solution of sulphate or acetate of iron be mixed with the reserve or paste for white, it will, when dipped and rinsed off, leave a buff or orange stain, not very strong, indeed, nor always very even; but applicable and useful in some cases. This paste has been long known and employed.

If instead of acetate of iron a strong decoction of bark, or French or Turkey berries, be mixed with the reserve, a yellow will be obtained, full, but less bright, than when raised in the weld copper.

Thus by combining different colouring matters with the mordants proper for fixing them on cloth, and also with substances which have the property of resisting the blue dye, various coloured pastes will be obtained.

The solutions of tin, from their forming combinations with most colouring substances which are but little affected by acids, seem likely to be of considerable use in the composition of pastes of this description. The muriate of tin destroys the resisting power of solutions of copper by de-oxygenating them; but the nitro-muriate, or highly oxygenated solutions, produce rather a contrary effect; they are these which should therefore be tried.

Of China Blue.

The process for China blue dipping consists in applying finely ground indigo, in its crude and undissolved state, upon the cloth, and fixing it by alternate immersions in solutions of sulphate of iron and lime.

The same thing takes place upon the cloth, that is effected in the ordinary blue vat when indigo is dissolved; in both cases the indigo is de-oxygenated, and prepared for solution by the copperas, and afterwards dissolved by the lime.

The different shades of colour in China blue dipping are produced by reducing, more or less, the standard colour, which is prepared in the following manner.

1st. Grind in a metal pot with balls, or by any other contrivance, 10 lbs. of good indigo, 8 lbs. of good copperas, and 5 lbs. of orpiment, with 2 gallons of water; when the whole is nearly ground, add two quarts of very thick solution of gum senegal, and grind a few hours longer.

2d. Prepare a solution of sulphate of iron by dissolving 2 lbs. in a gallon of water, adding a quarter of an ounce of pot-ashes, and suffering the precipitate, if there is any, to subside. Reduce the ground blue (No. 1) with as much of this clear solution (No. 2) as will bring it to a proper consistence for working, and print with this for the dark full blue. When dipped, this colour will have nearly the effect of black, especially in small bodies.

For pale blue, reduce the standard with 10, 15, or 20 measures of the solution of copperas, and an equal quantity of acetate of iron, or common iron liquor thickened with gum. With 50, 60, or even 90 measures of sulphate and acetate of iron, one measure of the standard blue will give very good shades of pale blue. When the pattern, whether block or plate, will not work in gum, a portion of the acetate of iron must be thickened with starch, or flour, and ground up in the mill with its due proportion of the standard. When worked on plates, wooden doctors, especially lime tree, are preferred to steel ones; they clean the plate much better, and give a fine neat impression.

The vats are of the same form, and generally of the same dimensions, as those before described; they are, however, never lined with lead; wood, or stone, being considered sufficiently secure for solutions of little value, compared with those of indigo. They are disposed in a line, a copperas vat, and a lime vat alternately; or when the mode of dipping allows it, a lime vat between two copperas vats, forming a system in which two frames are worked; the lime vat being thus kept constantly employed, the copperas vats only alternately. The copperas vats are made up of different strengths, according to the work intended to be done; strong thick goods, such as Marseilles quilting, &c. require stronger vats than calicoes and muslins. The first require the solution to be of spe. gravity 1040, the latter about 1030. These are the most economical points, but good work may be done at any point between 1025 and 1050. Lower than 1025, the colour will be pale and faint, though even; and higher than 1050, it is liable to be uneven, some parts being very deep and full, and others mealy and spoiled.

The lime vats are set with fine sifted quick lime, recently slaked, in the proportion of 150 lbs. to 1000 gallons of water.

When the pieces are hooked, and properly arranged on the frame, they are entered first into the lime, and the dipping proceeds as follows.

1.	Entry in the lime vat	5 minutes.
2.	in copperas vat	30
3.	in lime vat	10
4.	in copperas vat	30
5.	in lime vat	20
6.	in copperas vat	45
7.	in lime vat	45

During the first five minutes in the lime, the frame must be gently rocked, or moved up and down, then drawn up and tightened. The vat, both now, and at every subsequent dip, is well raked up before the frame is entered. When entered

in the copperas vat, rock five or six times, to detach the loose lime from the piece.

At the second entry in the lime, rock the whole time.

At the second, and every succeeding entry in the copperas vat, rock five or six times as before, to detach the lime.

At the third and fourth entry in the lime, rock five or six minutes, and now and then.

The reason for finishing out of the lime, is to keep the frames and hooks free from the rust and incrustation of the copperas, which it loosens, and renders more easy to detach and clean; with respect to raising the colour, it makes no difference whatever.

When the piece comes from the copperas vat the second time into the lime, it will appear a grass green colour, if there be a proper quantity of lime in the vat. If too little, the piece will appear yellowish, and more lime must be added.

Take off the pieces quickly after the last dip, and winch them briskly in the water-pit a minute or two at the most. Get them into the sours, and after winching over twice or thrice, let them lie an hour or two, after which winch again four or five times, and wash well in the wheel. Hot water them, and wheel again before hot souring, which is done in a sour of spec. gravity 1015, heated to 180°. Winch the goods four or five minutes in this, after which wash, hot water, &c. and finish for drying.

If the goods are kept too long out of the cold sour after the last dip, the oxyd of iron, with which they are coated, oxygenates very rapidly, and the cloth becomes buff or orange. It is with difficulty that the iron is disengaged, and not without long and very strong hot souring.

The cold sours soon become foul with the loose superfluous indigo, which is detached, and unfits them for light goods, long before the acid is saturated.

In this case it is economical to add two or three shovels full of fine well-beaten clay, previously mixed up with water; when this is well incorporated with the sours, and suffered to subside, it carries down with it great part of the floating indigo, and renders them fit for use again.

After every day's work the lime and copperas vats must be refreshed.

From 25 to 35 lbs. of sifted lime, according to the size of the vat, and the number of pieces that have been passed through it, must be added every night.

No harm can arise from excess of lime, excepting the unnecessary expence of more than is required, and the accumulation of sediment or mud in the vat which will soon require removing.

Ten pounds of copperas are generally added for every piece of calico that is dipped. This is suspended at the surface in a wicker basket, and suffered to remain till all is dissolved. It is quite unnecessary to rake up the vat, as the fresh additions of copperas will incorporate uniformly without stirring, which, by muddying the vat, may do mischief. Care must be taken to use the hydrometer frequently to correct any deficiency or excess which may arise in the sp. gr. of the solution of sulphate of iron.

In making new or fresh copperas vats, after having brought them to the standard on the hydrometer, add to every 1000 gallons four or five gallons of the lime vat (raked up) and one pound of potash. This is to neutralize the superabundant acid of the copperas.

The grass green Yorkshire copperas is the best for this purpose, it contains the least free acid; the pale whitish green is the worst, and when such is used it will be proper occasionally to throw into the vat about one pound of potash, and four or five gallons of muddy lime water.

When daily worked the lime vats should be emptied out, and wholly renewed once a month at least.

The copperas vats are never wholly emptied, but when the mud accumulates so as to be troublesome and endanger the safety of the work by resting on the lower edge of the piece, it must be taken out with a scoop or shovel proper for the purpose.

The ground of those goods which shew much white will in general be sufficiently clear when finished according to the preceding directions, the white is however greatly improved by a gentle soaping, and one or two days exposure on the grass.

In general, better work may be produced in the winter months than in summer: in hot weather, the colour is liable to be uneven, patched and mealy, the cause of this has not been well ascertained, though, in all probability, it arises from the increased action of the sulphate of iron and lime at an increased temperature: it is not unlikely that weaker copperas vats would be found to act better in summer than strong ones, as the effect of temperature would thereby in some degree be counteracted.

From the nature of the process of China blue dipping, it must be evident that it must precede any other application of colours to which the cloth is intended to be subjected. If, for instance, reds or yellows are to be introduced, these must follow the operation of dipping; as they would inevitably be ruined by repeated immersion in copperas and lime, or wholly discharged by cold and hot souring

Dipping, in *Magnetics*, is a certain degree of inclination, which a magnet or magnetic body, be it natural or artificial, endeavours to attain in most parts of the world. Amongst the properties of a magnet, this of its dipping undoubtedly is one of the most admirable; but with a magnet already possessed of its characteristic properties, this dipping is not easily discerned; it being difficult to say, whether the inclination of one of its extremities below the horizontal plane, and of course the elevation of its opposite extremity above that plane, is owing to the magnetic virtue, or to the want of mechanical balance, (*viz.* to its being heavier on one side of the fulciment than on the other,) and it was evidently on this account that the dipping of the magnet was not discovered so soon as its property of directing itself north and south, or nearly so. See Magnetism.

The easiest method of observing this magnetical property is as follows. Suspend an oblong and *unmagnetic* piece of steel either upon a vertical pointed wire, after the manner of a common compass-needle, or by fastening a fine thread to its middle; so that the oblong piece of steel may remain perfectly balanced, and of course horizontal. (A common oblong sewing-needle, having a thread fastened to its middle, will answer sufficiently well.) Then let this piece of steel or needle be rendered magnetic by the mere application of two powerful magnetic bars to its extremities; taking particular care not to disturb its point of suspension; and when this has been done, and the magnets have been removed, the piece of steel or needle will no longer remain in an horizontal situation, but one of its extremities will dip; that is, will incline itself below the horizontal plane, and its opposite extremity will raise itself above that plane, making an angle with it which is different in different parts of the world, and in some places it vanishes; that is, the needle will remain horizontal. This angle is also various in the same fixed place at different times; this latter variation however is but trifling. In England, the north end of the magnet tends downwards. A clearer idea of the different inclinations of the magnet, or magnetized steel, in different parts of the world, as well as

of the cause upon which that phenomenon depends, may be derived from the following experiment. Take a globular magnet, N S, *Plate* IV. *Magnetism fig.* 22, commonly called a *terrella*, or a magnetic steel bar, N S, *fig.* 23. (for by drawing a circle round the latter, one may easily figure to himself the form of a globular magnet.) The extremity N of this terrella, or steel bar, is its north pole, and the extremity S its south pole; and A is its middle, or equator. Place it upon a table as C D; then take another small and oblong magnet, or a common sewing-needle rendered magnetic; suspend it by fastening a fine thread to its middle, in such a manner as to remain in an horizontal position when not influenced by any other magnet. Now, if the said small magnet, being held by the upper part of the thread, be brought just over the middle of the large magnet, within two or three inches of it; you will find that it will turn itself so as to direct its south pole *s* towards the north pole N of the large magnet, and its north pole *n* towards the south pole S of the large one; it being a well-known law in magnetics, that poles of different denominations attract each other. It will be further observed, that the small magnet, whilst kept just over the middle A of the large magnet, will remain parallel to it or to its magnetic axis; for in that case the poles of the small magnet are equally attracted by the contrary poles of the large magnet, which are equidistant from the former. But if the small magnet be moved a little nearer to one end than to the other of the large magnet, then one of the poles of the former, namely, that which is nearest to the contrary pole of the latter, will incline itself towards it; and of course the other extremity will be elevated above the horizon. This inclination of the small magnet will be found to increase in proportion as it is brought nearer and nearer to one of the poles N or S; and, at last, if it be brought directly opposite to one of those poles, it will turn its contrary pole towards it, and will place itself in the same straight line with the axis of the large magnet, as is indicated by the figures 22 and 23, wherein the like parts are denoted by the same letters.

It must now be observed, that all the facts that have hitherto been noticed relative to the subject of magnetism, tend to prove, that the whole earth is, or must be considered as a large magnet; having its magnetic poles, magnetic equator, &c.: hence a magnetic needle, or any other magnet whatever, situated on different parts of the earth's surface, inclines, or tends to incline, the one or the other of its extremities, towards the horizon, or towards the axis of the earth, in the same manner and for the same reasons that compelled the small magnet *n s* of the preceding experiment to assume its various directions when placed in the vicinity of the large magnet N S. For, admitting that the north pole of the earth is possessed of a south magnetic polarity, and that the opposite pole is possessed of a north magnetic polarity, it follows, as is confirmed by actual experience, that when a magnet, properly shaped and properly suspended, is kept near the equator of the earth, it must remain in an horizontal situation; that if it be moved nearer to one of the poles of the earth, it must incline one of its extremities; namely, that which is possessed of the contrary magnetic polarity; that the said inclination must increase in proportion as the magnet, or magnetic needle, recedes from the equator of the earth; and, lastly, that when brought just over either of the magnetic poles of the earth, it must stand perpendicular to the ground; *viz.* in the same straight line with the axis of the earth.

The reader must not be surprised to hear that a south magnetism is attributed to the north pole of the earth; it being only meant, that it has a magnetic polarity contrary to that end of the magnetic needle which is directed towards it; and as we call the same end of the needle a north magnetic pole, we must of necessity attribute a contrary power, that is, a south magnetic polarity, to the northern part of the earth.—With a proper change of names, the same remark must be applied to the southern part of the earth; *viz.* it must be considered as being possessed of a north magnetic polarity.

By a little attentive consideration it will be easily comprehended, that the true and natural situation of a magnet, or magnetic needle, is a combination of its horizontal and vertical direction; *viz.* the magnetic needle endeavours to place itself in the plane of the magnetic meridian, and in a direction more or less inclined to the horizon, according as it happens to be situated, nearer to or farther from any of the magnetic poles of the earth. And this natural direction of the magnet is called the *magnetical line*. Therefore, in order to observe the true dipping of the magnet, the magnetic needle, or oblong magnet, must be placed in the magnetic meridian; *viz.* in the usual direction of the compass at the place of observation; otherwise the inclination of the magnet will be greater than it ought to be, as may be easily derived from a due consideration of the combined forces which act upon it. Hitherto we have considered the earth as an uniform and regular magnet, having the magnetic poles in its real poles, and its magnetic equator in its true or astronomical equator. And if such were the case, the dipping angle, which the magnetic needle makes with the horizon, would bear a certain determined ratio to the latitude of the place; so that by observing that angle, the latitude of the place might be deduced from it, without the need of any astronomical observation, which would prove of the utmost advantage to navigators; the case, however, is far different, as will be more particularly noticed in the sequel. For the present it will be worth while to mention, that after the discovery of the dipping property of the magnet, sanguine expectations were entertained respecting the advantages which might be derived from it, and it was imagined, that not only the latitude, but the longitude also of the place of observation, might be indicated by the dipping angle of the magnetic needle; for though it soon appeared, that neither the magnetic poles, nor the magnetic equator, of the earth, coincided with its true poles and true equator; yet that very same circumstance seemed to furnish the method of determining the longitude; which method was grounded upon the following principle; *viz.* that if the magnetic poles, though different from the real poles of the earth, be either fixed in other places, or do move with any regularity, it follows that the magnetic equator must likewise differ from the real equator; and must cut it at a certain angle; therefore, in the same parallel of latitude, but in different longitudes, the dipping angle of the magnet must be different; hence, by observing the dipping angle of the magnet at any particular place, the longitude of the place would thereby be indicated. Impressed with this idea, during a long period, subsequent to the discovery of the dipping of the magnet, the scientific world made various and strenuous exertions for the purpose of rendering that magnetic property subservient to navigation. Innumerable calculations were made, and various instruments were contrived. Mr. Henry Bond, a distinguished teacher of the art of navigation in London, calculated a table of latitudes corresponding to every five minutes of the inclination of the magnetic needle, and it was given out, that with this Mr. Bond's table, a good dipping needle, and the latitude of the place of observation, one might determine the longitude of any place in the world. Phil. Trans. v. viii. p. 6065. Mr. Bond was not the only projector of the kind. Messrs. Ditton, Whiston, and many others followed his example. Some were positive, others doubtful, and a few

cautious persons patiently awaited the result of experience; but the result of actual experiments soon proved the impracticability, or the insufficiency, of the projects, which were of course gradually neglected, and were lastly even ridiculed by the facetious Dean Swift. The principal object of calculation is to determine the nature of a curve which might pass through the poles of a large magnet, and to which curve a small magnetic needle may be a tangent at any point of its course. Or, in case of the earth, to calculate the inclination which the needle must have in any particular point of its surface. The data, however, upon which these calculations must be grounded, are uncertain. The magnetic needle is acted upon by both poles of the earth, and the law of that action is by no means well known; though it appears, both from experiments and calculation, that, most probably, the force of each pole varies in the inverse duplicate ratio of the distance. See Mr. Lambert's experiments and calculations in the Memoirs of the Academy of Berlin for 1756, and his second dissertation in the 22d volume of the same. We might refer our readers to other works, and we might also insert proper specimens of the calculations that have been proposed and actually made; but since the projects are neither established upon unquestionable principles, nor are they at all satisfactory, we shall not swell this article by the introduction of intricate investigations.

In short, it appears, from the concurrence of all the most accurate experiments and observations that have been made upon land as well as at sea, 1st, that the earth is not an uniform or regular magnet, but a very irregular one; for the ferruginous parts of it, (from the joint action of which the magnetism of the whole arises,) are irregularly disposed through it; whence it arises, that according as the magnetic needle is nearer to or farther from any ferruginous matter, so it is more or less influenced by it. 2dly, the magnetic poles of the earth are neither diametrically opposite to each other, nor indeed have philosophers as yet been able to determine their precise situations. Professor Krufft, in the 17th vol. of the Petersburgh Commentaries, places the north magnetic pole of the earth in lat. 70° North, and longitude 23° West of London; and the south magnetic pole in latitude 50° South, and longitude 92° East. Wilcke of Stockholm, in his indication chart, in the 33d vol. of the Swedish Memoirs, places the north magnetic pole in latitude 75° North, near Baffin's Bay, in the longitude of California, and the south pole in the Pacific Ocean, latitude 70° S. Churchman places the north pole in latitude 59° N. and longitude 135° W. and the south pole in lat. 59° S. long. 165° E. A planisphere by the Academy of Sciences at Paris for 1786, places the magnetic equator so as to intersect the earth's equator in long. 75° and 155° from the Island of Ferro, with an inclination of 12° nearly, making it nearly a great circle. But we are not informed on what authority, nor does this statement agree with the observations of the dipping made by British navigators. Mr. Churchman has given a sketch of a planisphere with lines which may be called parallels of the dip. Those parts of each parallel that have been ascertained by observation, are marked by dots, so that we can judge of his authority for the whole delineation. The magnetic equator cuts the earth's true equator in long. 15°, and 195° E. of Greenwich observatory, at an angle of 17° nearly. The circles of magnetic inclination are not parallel, being considerably nearer to each other on the short meridian than on its opposite. 3dly, the magnetism of the earth, *viz.* the positions of its magnetic poles, magnetic equator, &c. are subject to a gradual, but uncertain variation, which, in all probability, arises from the irregular heating and cooling, from the formation and decomposition of the different internal parts of the earth, and perhaps from other causes.

Notwithstanding the failure of the advantages which were expected from the dipping property of the magnet, it must be acknowledged, that the dipping needle, which shews the above-mentioned property of the magnet, seems, upon consideration, to be the principal instrument, from the indication of which we may expect to complete the magnetic theory of the terraqueous globe: it is therefore to be wished, that accurate, and at the same time least expensive, instruments may be contrived for the purpose; and that numerous as well as accurate observations may be made with them in every part of the world.

Discharging of Colour

DISCHARGING OF COLOUR, is frequently employed by dyers, to produce particular patterns upon the dyed ſtuffs. A manufacture of this kind has lately been introduced and proſecuted to great extent in the weſt of Scotland, for the purpoſe of manufacturing Bandana handkerchiefs, in imitation of thoſe imported from India. The material of which the fabric conſiſts is cotton, and the cloth is ſometimes tweeled, and ſometimes woven plain. The ground of the handkerchief is generally of the faſt dye, commonly known by the appellation of Turkey red, and this colour being afterwards diſcharged in particular places, a number of white ſpots are interſperſed upon the red ground. The proceſs is by no means complex, but as the manufacture is recent, has hitherto been chiefly, if not entirely, confined to the diſtrict where it originated, and has been much admired; an account of the engine employed, and of the proceſs, may perhaps deſerve ſome attention. In the Indian Bandanas, the white ſpots are generally placed in cluſters in the diagonal or diamond direction, and this diſtribution has been moſt frequently adhered to in the imitation handkerchiefs. The ſpots are ſometimes round, ſometimes ſquare, and ſometimes, though more rarely, triangular. Previous to the diſcovery and introduction of the diſcharging proceſs, as applied to this manufacture, many imitations of the Bandanas had been made by the common mode of calico-printing. But the colours of the printed handkerchiefs, beſides being leſs brilliant at firſt, were found to fade ſo ſoon, that the diſcharged ones do already, in a great meaſure, and will probably very ſoon entirely, ſuperſede them.

The engine employed is a very ſtrong preſs, the whole framing of which is generally of caſt iron. In conſtructing this preſs, it is abſolutely neceſſary that every part ſhould be ſo ſtrong, as to bear a very great preſſure without yielding in any part. A ground plan, and tranſverſe elevated ſection of it, are given in *figs.* 3. and 4. *Plate* VIII. *Miſcellany*.

The pattern to be formed is cut upon two flat plates, which exactly correſpond. They are uſually of caſt iron, and the lower plate is faced with copper, or ſome metal which will both receive a fine poliſh, and reſiſt, to a great degree, the corroſive power of the diſcharging liquor, which is compoſed of a preparation of the oxy-muriate of lime diluted with water. In the under plate, which muſt be perfectly ſmooth and level, a hole is cut for every ſpot which is to be diſcharged. In the upper plate, or cover of the preſs, every ſpot is formed by a hollow tube of braſs or copper, which is tightly driven into a hole formed in the plate, and cemented with a compoſition of white lead and oil, or any other cement, which will prevent the diſcharging liquor from eſcaping by any other paſſage than thoſe through the perforated tubes.

In the ground plan (*fig.* 3.), little more of the preſs will be ſeen than the upper ſurface of the cover, which is diſtinguiſhed by the letters A, A, A, A, placed at each corner. About the upper plate or cover is a rim to prevent the diſcharging liquor from running off, which is diſtinguiſhed by the letters B, B, B, B.

At each corner of the plate is a round hole, working upon a pin faſtened in the under plate or ſole of the preſs, to guide the bottoms of the perforated tubes perpendicularly over the holes in the lower plate. Beſides theſe guides, there are two notches C, C, which graſp the upright pillars D, D, and thus the upper plate, when riſing and ſinking, is guided in ſix different places. The elevation and depreſſion of the cover is effected by turning the ſcrew E. The form of the upper and under plates, and the pattern being repreſented by *fig.* 3, the remaining parts of the preſs will be more clearly ſeen by referring to *fig.* 4, which is a tranſverſe elevated ſection of the preſs, cut in the direction of the dotted line F F, *fig.* 3.

The letters of reference in *fig.* 4, are the ſame for each part, as in *fig.* 3, but ſome parts are diſtinctly ſeen in the latter, which do not appear in the former, and theſe are diſtinguiſhed by additional letters. As in *fig.* 3, AA repreſent the upper plate or cover of the preſs. The rims are ſhewn by the letters B, B. The notches which graſp the upright pillars are marked C, C, and the pillars D, D. The ſcrew which raiſes and ſinks the cover of the preſs is diſtinguiſhed by the letter E. Between the pillars D, D, is an arch of iron H H, in the centre of which is a box I, containing a female ſcrew for working the ſcrew E. The lower part of the ſcrew E revolves in the ſocket G fixed to the cover of the preſs, and thus raiſes or ſinks it as may be neceſſary. Upon the ſcrew E, is fixed a wheel K K, through the arms of which is put the lever uſed for ſcrewing down and raiſing the cover, as in other large preſſes. The ſole or bottom of the preſs is diſtinguiſhed by the letters L, L. It is placed exactly in a horizontal direction, and is ſupported by ſix ſtrong iron perpendicular legs, namely, one at each corner, and the lower parts of the pillars D, D, in the middle. Between the cover and bottom, the cloth to be diſcharged is placed at M M.

The mechanical part of this proceſs is, in almoſt every reſpect, entirely ſimilar to that uſed by cloth dreſſers, bookbinders, and many other tradeſmen who employ ſtrong ſcrew preſſes. To enſure the accuracy of its operation, correctneſs of workmanſhip, and ſtrength, are all that are neceſſary, and theſe are indiſpenſable. The preſs muſt be fixed, ſo that both the cover and bottom may be horizontal planes. The bottom muſt be perfectly level, and the perforated tubes in the cover muſt all exactly touch the bottom, with equal preſſure. The perforation of the tubes muſt alſo correſpond exactly with the holes or apertures in the bottom, and the guides muſt be fitted to work freely, but at the ſame time to prevent any aberration of the cover in riſing or ſinking. From the great preſſure neceſſary when the cover is ſcrewed down, great care ought to be taken that the whole of the ſupporters of the preſs be exactly perpendicular, and that the preſs, when properly placed, ſhould be ſtrongly ſecured.

The apparatus being well made and properly ſecured, the proceſs of manufacture is remarkably ſimple. The cloth is woven of the natural colour of the cotton wool, and in this particular the manufacture, beſides the beauty of its appearance, poſſeſſes a decided preference, in point of economy, over the Pullicate handkerchiefs, and other imitations of the

Indian manufacture, where the pattern is produced in the loom, and the stuff previously dyed in the state of yarn. Whatever care has been taken to prevent the tedious and repeated processes, which are used in the dyeing of Turkey red, from injuring the yarn, every person, at all conversant with the manufacture of coloured yarn, will be sensible that all the subsequent stages of the operation of forming it into cloth are much impeded by the preparatory change which it has undergone in the dyers' hands; and from the nature of the process this perhaps applies to no colour in so great a degree as to Turkey red. It follows that the wages given to winders, warpers, and weavers, must be raised in proportion to the impediments which they have to encounter, and to the smaller quantity of cloth which their exertions can of consequence produce. Besides this, all handkerchiefs ornamented in the loom, are confined to what is called *checking;* and all the various colours must be interwoven either parallel or at right angles to each other, unless very complicated and consequently expensive mounting be used. The time consumed in changing the colours of the woof also impedes, in no small degree, the speed of the operation; and thus both the state and nature of his materials, and the mechanical operation necessary to accomplish his purpose, tend at the same time to enhance the wages of the weaver, in proportion to the quantity of cloth which is the product of his labour.

But as the imitation Bandanas are woven perfectly plain, the same as calicoes, cambrics, and other stout fabrics, no impediment of this kind occurs, and the whole labour and expence are in the subsequent process, and the sum sunk in procuring the press.

After the cloth is woven, it is cleared from impurities, and dyed Turkey red, exactly in the same way as yarn is dyed. When the colour is to be discharged, the cloth is neatly folded in squares, of about 10 or 12 folds, and laid upon the sole or under plate of the press, the cover being previously elevated by means of the screw and wheel. When the cloth has been properly disposed, as at M M, the cover is brought down in contact with its upper surface, and a lever being applied to the screw and wheel, the upper and under plates are firmly screwed together, the cloth being between them. The under part of each of the perforated tubes now presses hard upon the upper surface of the cloth, and being perpendicularly over the holes in the under plate, no part of the discharging liquor can escape, excepting through the apertures which form the pattern. These apertures are distinguished in the section, *fig.* 4, by the numbers 1 to 8. The press being screwed down, the discharging liquor is poured upon the cover, and being confined by the rim passes through the apertures, and discharges the colour from those parts of the cloth which it passes through, being prevented from spreading upon any other part by the power of the screw. The discharging liquor is received into a trough placed under the lower plate of the press, and distinguished by the letter N. From this trough it is conveyed, by a spout, into vessels placed to receive it, and preserved; for although it loses much of its chemical quality in passing through the cloth and discharging the colour, it retains so much as still to be of service in many of the inferior operations of clearing and whitening of cloth. The discharge of the colour is effected by the action of the liquor in about eight or ten minutes. When the liquor has passed through, the cover of the press is raised, the cloth is taken out, and another piece being substituted, the operation goes on as before.

When two industrious persons are employed, for the purposes of folding the cloth, working the press, and applying the liquor, it is calculated, that the operation, for one piece of 12 handkerchiefs, occupies about 15 minutes; consequently, two persons can discharge 48 or 50 dozens of handkerchiefs in one day of 12 working hours.

The operation requires only care and attention; for if the press be properly constructed, nothing more is required than to fold the handkerchiefs neatly, to lay them square upon the under plate of the press, and to be careful that the cover is tightly screwed down before the liquor is applied. When the handkerchiefs are taken from the press, the discharged spots do not appear white, but of a dull straw colour. The common operation of clearing, however, very soon gives a pure white to the spots, and adds brilliancy to the Turkey red ground. Those who have been longest in the habit of working these presses, consider a most important point to be, attention to the cement which is put where the perforated tubes are connected with the cover of the press. This certainly requires frequent and careful examination; for if any of the liquor is allowed to escape here, the ground of the handkerchiefs will be materially injured by its operation upon the colour. As the invention is recent, and the study of practical chemistry rapidly advancing, it is not improbable that some composition of superior efficacy, for this purpose, may soon be discovered. The cement used answers the purpose tolerably well, but requires great attention on the part of the person to whom the charge of the press is entrusted.

It has been already observed, that the chemical liquor generally employed is a solution of the oxymuriate of lime.

The method of preparing this liquor was discovered and first introduced into practice by Charles Tennant, esq. St. Rollocks, near Glasgow; and is, at present, universally used by those engaged in the manufactory. The following remarks, upon its practical application, have been obligingly communicated to the writer of this article by that gentleman, which he will copy in his own words:—

"Agreeable to my experiments, a solution of the oxymuriate of lime, of 1.010 specific gravity, decomposed by $\frac{1}{100}$th part of its weight of sulphuric acid, of 1.846 specific gravity (the usual quality of marketable ore), is the most advantageous preparation for discharging Turkey red; and what, I believe, is in pretty general use with the trade in this quarter.

"As the oxymuriatic acid is but little soluble in water, when disengaged from its combination with the lime, the sooner it is used, after its separation by the sulphuric acid, the better; and this is done by simply filling the types with the solution, and allowing it to remain in them for so many minutes as proper, until the discharge is effected.

"When the discharge is completed, the acid liquor must be carefully washed out of the types previous to their being removed from their hold of the cloth."

It is hardly necessary to observe, that the word types, used by Mr. Tennant, refers to the perforated tubes fixed in the cover of the press, and previously described in the mechanical part of this article.

Some alteration in the construction of the presses has very recently been introduced into some of the manufactories. The chief difference from the press represented, consists in pressing down the cover by a great weight, instead of the action of the screw. Water has been used to give this weight, and is raised into a trough upon the cover by means of a forcing pump, when the pressure is to take place. This may certainly press more equally over the whole surface of the cover than a screw, which acts only upon one point, and in this particular may be an improvement. Few of these presses have, as yet, been used; but those which have, are said to answer very well.

Distiller

DISTILLER, a perfon who diftils fpirits for fale. By 43 G. III. c. 69, every diftiller or maker of low wines or fpirits for fale, or exportation, within England, fhall take out a licence, which fhall be charged with the yearly fum of 10*l.*; and every rectifier of fpirits within England fhall pay for fuch licence a duty of 5*l.*; and fuch licence fhall be renewed annually before the end of the year, on pain of forfeiting, if a common diftiller, 200*l.*; if a molafs diftiller or rectifier, 30*l.*; 24 G. III. c. 41. No perfon fhall be deemed a rectifier or compounder who fhall not have an entered ftill capable of containing, exclufive of the head, 120 gallons; which fhall have fuitable tubs and worms, and be ufed for rectifying Britifh fpirits for fale, 26 G. III. c. 73. By 19 G. III. c. 50. every fuch diftiller fhall caufe to be put up in large characters, over the outward door of every place ufed for making or keeping of Britifh-made fpirits, the words *Diftiller, Rectifier,* or *Compounder* of *Spirituous Liquors,* on pain of 100*l.*; and if any perfon fhall buy any fuch fpirits of any perfon not having fuch words over his door, he fhall forfeit 50*l.* By 21 G. III. c. 55, if any diftiller or dealer fhall buy any Britifh made fpirits (except, as in the former cafe, at the public fales of condemned fpirits by the commiffioners of excife) he fhall forfeit 500*l.* By 19 G. III. c. 50, no perfon fhall be permitted to make entry of any workhoufe or place, or of any ftill or utenfil for making, diftilling, or keeping of low wines or fpirits, unlefs he fhall occupy a tenement of 10*l.* a year, affeffed in his own name, and paying the parifh rates: and by 21 G. III. c. 55, in order to prevent private diftillations, every perfon who fhall make or diftil any low wines or fpirits, whether for fale or not for fale, fhall be deemed a common diftiller for fale, and fhall enter his ftill and veffels at the next office of excife; and every perfon making or keeping any wafh fit for diftillation, and having in his cuftody any ftill, fhall be deemed a common diftiller for fale, and be liable to the feveral duties, and fubject to the furvey of the officers. No common diftiller or maker of low wines, fpirits, or ftrong waters for fale, fhall fet up any tun, cafk, wafh-back, copper, ftill or other veffel, for making or keeping any worts, wafh, low wines, fpirits, or ftrong waters; nor alter nor enlarge the fame, nor have any of them private or concealed, or any private warehoufe, cellar, &c. for making or keeping any the faid liquors, without firft giving notice at the next office of excife, on pain of 20*l*; and he in whofe occupation any of the fame fhall be, fhall forfeit 50*l.*; 8 and 9 W. c. 19. And by 24 G. II. c. 40. every diftiller fhall, 10 days before he diftils or makes any fpirituous liquors, enter every veffel, &c. at the next office of excife; on pain of 50*l.* for every ftill or veffel ufed and not entered. And every diftiller fhall, four days before he begins to brew any grain, &c. make entry at the next excife office, of all coppers, veffels, &c. inferting in fuch entry the day on which he intends to begin, and the ufe to which fuch veffel is to be applied; which fhall not be altered on pain of forfeiting 100*l.* with the liquor, which may be feized by any officer of excife, 26 G. III. c. 73. And by 21 G. III. c. 55, no perfon fhall make ufe of any veffel, room, &c. for making wafh for the diftillation of low wines and fpirits, without giving notice at the next office of excife, on pain of 50*l.* for every veffel, room, &c. ufed without notice. Nor fhall any perfon withdraw his entry whilft any duty is depending, or any veffels are ftanding, except by changing it on the day of its being withdrawn, 23 G. III. c. 70., 26 G. III. c. 73. No perfon is allowed to have any ftill or number of ftills, which fingly or together contain lefs than 100 gallons, under the penalty of 100*l.* for every ftill; and the wafh-ftill fhall contain at leaft 400 gallons, exclufive of the head, under the fame penalty, 2 Geo. III. c. 5. and 14 Geo. III. c. 73.

Diftillers are to fhew to the officer every ftill or other veffel entered; and the veffels are to be marked by the gauger; and defacing the mark, or rubbing out, incurs a penalty of 20*l.* 26 Geo. II. c. 40.

Diftillers who ufe private pipes, &c. for conveyance of diftilled liquor, forfeit 100*l.* 10 and 11 W. c. 4. They fhall alfo make holes in the breaft of the ftill for taking gauges and famples, and provide locks on the ftill-heads, the holes, difcharge-cocks, and furnace-door, under a penalty of 50*l.* and of 200*l.* for breaking or wilfully damaging fuch lock or faftening, after it has been fecured by the officer, 12 Geo. III. c. 46. 14 Geo. III. c. 73.

The diftiller fhall provide proper ladders for the officer to examine each ftill, and affift in fetting them up, on pain of 200*l.* 23 G. III. c. 70.

Distillers are required to give notice to the officer of excise, before they receive any wine, cider, &c. or any kind of fermented wash, on pain of 50*l.* and also before they charge or open the still, expressing and describing the number and marks of the wash-batches used; and they are prohibited from charging the still with any other, under a penalty of 100*l.* 24 G. II. c. 40; 12 G. III. c. 46; 14 G. III. c. 73.

Distillers, in preparing grist for wash, that use more than in the proportion of one quarter of wheat to two quarters of any other grain, forfeit 50*l.* 33 G. II. c. 9.

If any corn distiller, or maker of low wines or spirits from corn or grain, shall make use of any molasses, coarse sugar, honey, or any composition or extract of sugar, in brewing or preparing his wash for distillation, or receive such materials into his custody, exceeding 10lbs. in weight, he shall forfeit 100*l.*; and officers may take samples of the wash in any vessel, paying for the same at the rate of 1*s* 6*d.* a gallon; and if the distiller shall obstruct him, he shall forfeit 100*l.* 23. G. III. c. 70.

Officers are to attend at the still-house, after due notice, to see that the wash-stills are properly filled, and when they are fully charged to lock and secure them. And if any person shall open any still-head, &c. after they have been so locked, and before they are opened by the officer of excise, or shall wilfully damage any lock or fastening, he shall forfeit 200*l.* 12 G. III. c. 46.

Removing or concealing wash, &c. in the possession of any distiller, incurs a forfeiture of the same; and such distiller, and the person employed to remove, or who shall receive the same, shall severally forfeit 10*s.* for every gallon of it; and no wort, wash, &c. shall be put into the still, or removed from the back or vessel in which it was fermented, till the same has been gauged; in the penalty of 200*l.* and double duty.

The officer shall every three months, if required, take an account of the stock of all distillers and rectifiers, and if any unfair increase shall be found, the same shall be forfeited, and may be seized; and the person in whose stock such excess shall be found shall forfeit 50*l.* Rectifiers are to mark the strength and quality of mixed spirits on the outside of the cask, and in default thereof, or if untruly marked, the same shall be forfeited, and also the casks, and may be seized; and the rectifier shall forfeit 50*l.* 26 G. III. c. 73.

By 27 G. III. c. 31, made perpetual by 41 G. III. c. 97, it was enacted, that all spirits should be deemed and taken to be of the strength indicated by Clarke's hydrometer, but by 43 G. III. c. 97. the lords of the treasury may discontinue the use of this hydrometer, and direct any other to be used in lieu of it. All British spirits of the third extraction, or which have been twice distilled from low wines, and had flavour communicated to them, shall be deemed "British brandy;" if no flavour has been communicated to them, the same shall be deemed "rectified British spirits." If of the second extraction, or once distilled from low wines, the same shall be deemed "raw British spirits." And all British spirits distilled with juniper berries, carraway seeds, anise seeds, or other seeds, or ingredients used in the compounding of spirits, shall be deemed "British compounds." And all British spirits of a greater strength than one to two over hydrometer proof, shall be deemed "spirits of wine." Officers shall take an account of the stock of rectifiers and compounders every three months at least, and if any increase of quantity, under certain limitations, be found, the quantity in excess shall be forfeited, and may be seized; and such person shall forfeit 50*l.* And if any British spirits or compounds are sent out of a greater strength than one in five under hydrometer proof, the same shall be forfeited, and treble value, or 50*l.* in the whole; and the same may be seized, with the casks and vessels containing it. 30 G. III. c. 37. The distiller shall weekly make entry of all wash by him used for the making of low wines and spirits within each week, on pain of 10*l.*; and within a week after shall pay off the duties, on pain of double duty. 19 G. III. c. 50. All permits for removing British spirits shall correspond with the request notes, and delivered with such spirits to the buyer, on the forfeiture of the same to such buyer, and double the price including the duties: and such buyer may be admitted to prove, that such spirits were delivered without a lawful permit: but no buyer shall be allowed to avail himself of such forfeiture, unless complaint is made within fourteen days after the delivery of the spirits. 26 G. III. c. 73.

Retailers of distilled liquors, or such as sell the same in less quantity than two gallons, must take out a licence, for which they are to pay annually a sum corresponding to the rent of the premises which they occupy; if the rent of such retailer be 15*l.* or upwards, 5*l* 2*s.*; at 20*l.* and upwards, 5*l.* 10*s.*; at 25*l.* and upwards, 5*l.* 18*s.*; at 30*l.* or upwards, 6*l.* 6*s.*; at 40*l.* or upwards, 6*l.* 14*s.*; and at 50*l.* or upwards, 7*l.* 2*s.* This licence, which is to be renewed annually, on the penalty of 50*l.*, is to be granted only to those who keep taverns, victualling-houses, inns, coffee-houses, or ale-houses; who, within the limits of the head office of excise in London, pay 10*l.* a year rent and parish rates, and in places where the occupiers are not rated 12*l.* a year; and who, in other parts of the kingdom, pay to church and poor. They must first be licensed to sell ale in the places where they dwell.

By 16 G. II. c. 8. retailers of spirituous liquors, without licence, were subject to a penalty of 10*l.*; and by 24 G. II. c. 40. all liquors found in the custody of such persons, or within six calendar months after conviction, were to be seized. And by 13 G. III. c. 56, and 30 G. III. c. 38, such retailers are to forfeit 50*l.*, subject to mitigation so as not to be reduced below 5*l.* Every person, who shall retail less than two gallons, shall enter his warehouses, shops, &c. and his spirituous liquors, on pain of 20*l.* for every place, and 40*s.* for every gallon not entered; and also the liquors and casks. 9 G. II. c. 23. 30 G. III. c. 38. By 19 G. III. c. 69. every importer or dealer in spirituous liquors, shall cause to be painted, on a conspicuous part of the house, shop, or cellar, &c. used by him, the words *Importer of*, or *Dealer in*, *Spirituous Liquors*, on pain of 50*l.* Any importer or dealer buying of a person, who has not these words over the door of his shop, &c. shall forfeit 100*l.* Any person, who hath not made entry of his liquors, and who hath these words over his door, shall forfeit 50*l.* No spirituous liquors shall be brought into a place of sale, without previous notice to the officer of excise, and leaving with him a certificate, expressing that all the duties are paid, the quantity and quality, the name of the seller, &c. on pain of forfeiting 20*l.*, and also the liquor and casks. 9 G. II. c. 23. Retailers shall not increase the quantity of their liquors, on pain of 40*s.* a gallon; and the liquors so mixed with water, or any other liquors, shall be seized and forfeited. 9 G. II. c. 23. By 21 G. III. c. 55. the stock increased shall be forfeited, a quantity equal to the increased quantity shall be seized by the officer, and the person offending shall forfeit 20*l.* The officer may, at all times, by day or night, enter into warehouses, shops, or other places, to take an account of the quantity and quality; and if any retailer hinder the officer, he shall forfeit 50*l.* 9 G. II. c. 23. No licensed retailer shall have any share in a distillery or rectifying house, or be concerned in such trade, on pain of 200*l.* 26 G. III. c. 73.

Hawkers of spirituous liquors in the streets, &c. are

liable to a forfeiture of 10*l.* 9 Geo. II. c. 23. 11 Geo. II. c. 26. Perfons giving away fpirituous liquors, or paying wages in them, fhall be deemed retailers. 9 Geo. II. c. 23. Keepers of gaols, workhoufes, &c. felling fpirituous liquors, or knowingly fuffering them to be fold, except fuch as are prefcribed by a phyfician, furgeon, or apothecary, forfeit for the firft offence 100*l.* and for the fecond their office. Perfons bringing any fuch liquors into any place of that kind may be apprehended, and on conviction committed to the houfe of correction or prifon for any time, not exceeding three months, unlefs they immediately pay a fine, not exceeding 20*l.* nor lefs than 10*l.* Debts for fpirituous liquors cannot be recovered, unlefs they have been contracted, or the liquors delivered at one time to the value of 20*s.* or upwards: and diftillers knowingly felling or delivering diftilled liquors to unlicenfed retailers, forfeit 10*l.* and treble their value; and the retailer, convicting the diftiller, is entitled to a fhare of the penalty, and is himfelf indemnified. Perfons riotoufly refcuing offenders, or affaulting informers, and their aiders or abettors, are guilty of felony, and liable to feven years' tranfportation. 24 Geo. II. c. 40. If any perfon fhall obftruct any officer in the execution of his duty, in relation to this act, he fhall forfeit 200*l.* 23 Geo. III. c. 81. No liquor exceeding one gallon fhall be removed without a permit. 6 Geo. I. c. 21. Britifh fpirits made from corn are allowed on exportation as merchandize, a bounty or drawback of 3*l.* 12*s.* *per* ton. 5 Geo. III. c. 5. 27 Geo. III. c. 13. And by 6 Geo. II. c. 17. for fpirits drawn from Britifh corn, a drawback was to be allowed at the port of fhipping, of 4*l.* 18*s.* *per* ton, in full of all drawbacks: and by 23 Geo. II. c. 9. there was to be an additional drawback of 24*l.* 10*s.* a ton, on all Britifh made fpirits exported; provided that they are not exported in cafks containing lefs than a hundred gallons, and in veffels of lefs burden than a hundred tons, except to Africa and Newfoundland, whither they may be exported in any veffels not lefs than feventy tons. 6 Geo. III. c. 46. The 43 Geo. III. c. 69, which confolidates the duties, &c. of excife, continues all advances, bounties, and drawbacks, which are particularly directed to be made by any act or acts of parliament in force, on or immediately before 5th of July, 1803, except fo far as fuch allowances may be varied or repealed by the faid act. By 39 and 40 Geo. III. c. 73. fpirits diftilled in England for exportation to Scotland, are exempted from the excife duties in England. And by 43 Geo. III. c. 69, for every gallon, Englifh wine meafure, of fpirits, not exceeding in ftrength that of one to ten over hydrometer proof, and fo in proportion for any higher degree of ftrength, made in England and thence imported into Scotland, payment is to be made by the importer before landing, of 4*s.*; and by c. 81. an additional duty of 2*s.*: for every fuch gallon manufactured in Scotland and brought from thence into England, 5*s.* $0\frac{1}{2}$*d.*; and by c. 81. an additional duty of 2*s.* 5*d.* For every gallon of fuch fpirits of greater ftrength than one to ten over hydrometer proof, and not exceeding 3*l per cent.* over and above one to ten over hydrometer proof, 7*s.* $5\frac{1}{2}$*d.* and a furcharge. And all duties and drawbacks under thefe acts fhall be proportionate to the actual quantity. No fpirits fhall be fent from Scotland to England, or from England to Scotland by land, or in veffels of lefs than 70 tons burden, or in cafks containing lefs than 100 gallons, on forfeiture of the fame, together with cafks or package; and alfo the veffels, boats, horfes, cattle, and carriages employed, which may be feized. 28 Geo. III. c. 46. And if any diftiller, rectifier, compounder, or dealer in fpirits, or fervant belonging to any fuch perfon, fhall obftruct any officer in the execution of this act, he fhall forfeit 200*l.*

DISTILLERY, the art of diftilling brandy and other fpirits. This art was firft brought into Europe by the Moors of Spain about the year 1550: they learned it of the African Moors, who had it from the Egyptians; and the Egyptians are faid to have practifed it in the reign of the emperor Dioclefian, though it was unknown to the ancient Greeks and Romans. Anderfon's Hift. of Commerce, vol. i. p. 83. See FERMENTATION, and MALT *Diftillery.*

Docks

Docks, probably from δοχιον, *receptaculum*, of δεχομαι, *I receive*, are artificial baſons, or excavations, under different denominations, formed for the convenience of receiving ſhips, in rivers and harbours, for the purpoſe of repairing, or for loading and unloading their cargoes, out of the influence of the tide. They are conſtructed of brick, ſtone, or timber; with locks or flood-gates, pointed to or from the tide, to keep the water in or out, as the object and nature of the docks require.

Wet Docks are for the reception of ſhips to lie afloat while loading or unloading, with gates pointed from the tide, to keep the water in at low water. Locks are attached thereto, with double gates, for the more eaſy admiſſion and egreſs of ſhipping, without loſing more water than neceſſary; and to aid the operation of opening and ſhutting theſe gates, ſluices are made within the ſame, to regulate the water within the locks, until the ſame level is produced within as without, ſo that the gates may open with facility.

Dry Docks are of various kinds,

1. Baſons, or docks open to the tide, are called dry docks, becauſe the veſſels frequenting them ground at low water, and lie dry on the ebb tide, and float again on the next riſe of the tide. They are uſed at Liverpool as entrances to the wet docks, and are frequented by coaſters, and ſmall or light veſſels, that do not injure by lying on the ſhore.

2. *Graving Docks*, for repairing of ſhips, are excavations with flood-gates pointed towards the tide, to keep the water out while ſhips are under repair. Veſſels are admitted at high water, and the gates are ſhut at low water; and when

the repairs are completed, the gates are again opened before the riſe of the tide, and the veſſel is on the flood hauled out of dock. In ſome countries, where there is little or no tide, theſe docks are ſo conſtructed, as to have the water within forced out by pumps, or other mechanical operations, as in Ruſſia and other parts.

In ſome places, as at Portſmouth, floating gates are conſtructed, in the form of a veſſel, with each end like the bow of a ſhip, neatly fitted to the lock, and to work up or down a groove in the lock with the tide, by pumping water into, or out of the veſſel, ſufficient to float or ſink it, as occaſion might require. A veſſel of this kind was alſo uſed at the London docks, to keep the water out while they were making.

3. *Slips* for the building of ſhips, may be claſſed under this head. They alſo are excavations, ſloping and inclined towards the tide, well framed and floored with timber, &c. Ships, when built, are generally launched at ſpring tides, by driving away the ſhoars and props which ſupported them, when they are eaſily launched from off the ſlips.

Naval Docks.—Portſmouth, Plymouth, Chatham, Sheerneſs, Woolwich, and Deptford, are the principal naval arſenals of Great Britain; where ſhips of war of every deſcription from ſloops to ſhips of the line of 130 guns, are built and repaired, and when finiſhed are turned out of dock: other countries have ſimilar eſtabliſhments.

Commercial Docks.—The convenience and advantages of wet docks for the ſecurity of ſhipping and the diſpatch of buſineſs are become objects of great attention in many countries for commercial purpoſes. The adoption of them within this laſt century has been no where more general than in Great Britain. The docks now made and making, at London, Liverpool, Hull, Briſtol, Leith, &c. have contributed, and will greatly contribute (combined with our natural advantages) to the increaſe of our commerce, wealth, and population. They have formed our great leading ports into depots, and have given, aided by the extenſion of the bonding ſyſtem, great facilities to commerce by ſuſpending, in many caſes, the payment of duties until goods are taken out for home conſumption. Docks, while giving protection, convenience, and diſpatch to commerce, ſhipping, and revenue, happily link and unite, by means of rivers, roads, and canals, our foreign with our domeſtic commerce.

Liverpool Docks.—The port of Liverpool, from the badneſs of its harbour, the rapidity of the Merſey, and the ſhifting of its ſands, was obliged, at an early period, to reſort to docks: for this purpoſe an act was paſſed in 1708. What neceſſity firſt dictated, has ſince been one of the principal cauſes of the town becoming, through the enterpriſing ſpirit and induſtry of its inhabitants, the ſecond port in the kingdom, for commerce, ſize, and population. In the courſe of one century there have been eſtabliſhed within that port, five wet docks, three dry docks, and five graving docks, independent of the duke of Bridgewater's dock, for canal purpoſes; and a plan is now in execution for making two additional wet docks, and enlarging Queen's dock, which is propoſed to be connected with the Merſey by means of a new floating dock, and a dry harbour baſon. Almoſt all theſe docks are, more or leſs, encroachments on the banks of the river.

By the act paſſed in 1708, authority was obtained to make the firſt dock and baſon for the ſecurity of ſhipping and the loading and unloading of the ſame. The management of the undertaking was inveſted in the corporation for the term of 21 years, which gave for this purpoſe four acres of land, and they were impowered to borrow the ſum of 6000*l.* In 1717, the term was prolonged for 14 years, and they were authorized to borrow 4000*l.* more. In 1737, the term was further extended to 31 years, and powers given to make an additional dock, to build a pier in the open harbour, and to light the docks. The corporation on this occaſion gave ſeven acres of land, and they were impowered to borrow 6000*l.* In 1761, the commerce of Liverpool was ſo much increaſed, and its ſhipping had become ſo numerous, and ſo enlarged in ſize, that further accommodation was wanting. The term of the corporation's management was again extended for 21 years, with powers to make another dock, and to erect a light-houſe for the benefit of the port; for theſe purpoſes they were authoriſed to borrow the ſum of 25,000*l.*, and to raiſe the further ſum of 2000*l.* on the light-houſe duties. In 1784, the powers of all the former acts were enlarged, and the term extended to 41 years, with liberty to make two additional docks and piers, and to borrow for this purpoſe 70,000*l.* In 1799, an act was paſſed to alter and enlarge the powers of former acts, and to render the docks and the port more commodious and ſafe; by which a further extenſion of term was granted for 30 years. The corporation again gave ſome lands, and they were impowered to make two additional docks, and other docks; with liberty to raiſe the ſum of 120,000*l.*, and to double the former tolls.

Under the authority of theſe various acts of parliament the ſeveral docks have been conſtructed, and it has been found that each ſucceſſive improvement, by affording additional convenience to foreign trade, has been followed by its increaſe, and prepared the way for the further extenſion of this excellent ſyſtem of accommodation at future periods. The names and dimenſions of the docks are as follows, and a plan is annexed on a ſcale of double the ſize of the plan of the docks for London. See *Plate of Docks.*

Docks.	Long.	Broad.	Area.	Stat. Mea.	Dock Gates.		Quay.
					Broad.	Deep.	
No.	Yards.	Yards.	Square Yds.	A. R. P.	Feet.	Feet.	Yards.
1 Old Dock - - - -	200	70 to 90	17,070	3 2 4	34	23	652
2 Salthouſe - - - -	irregular.		22,420	4 2 21	34	23	640
3 George's - - - -	250	100	26,068	5 1 2	38	25	670
4 King's - - - - -	290	90	25,650	5 1 8	42	25	715
5 Queen's - - - - -	270	130	33,600	6 3 31	42	25	780
Baſons.			124,808	25 2 26			
6 To the Old Dock - - - - - - -			19,298	3 3 34			
7 To George's Dock - - - - - -			12,090	2 3 0			
8 To King's and Queen's Docks - - - -			14,420	2 3 37			
			170,616	35 1 17			

Theſe

These wet docks are all for ships from foreign voyages. The dry docks are for coasters, and other small and light vessels. There are five graving docks, which are from 390 to 490 feet long, and hold two or three vessels for repair, at a time. No. 9. The duke of Bridgewater has a dock at Liverpool, connected with his canal concerns, calculated to hold 42 canal flats, of 50 tons, such as No. 10 in *Plate of Docks.*

The docks are surrounded with convenient and spacious warehouses for the reception of goods; and a tobacco-warehouse capable of containing 7000 hogsheads.

The several docks are connected with each other by means of tunnels or sluices under ground, for the purpose of scouring them when they want cleansing. This is effected by letting the water off from any one of them, and opening the sluices into it in different directions; while a number of men with shovels throw the mud into the currents, which is thus washed into the river, and in the course of about 12 or 14 days the dock is sufficiently cleared.

Accurate tide tables are kept, from which it appears that the rise of the tide in the river is about 30 feet at spring tides, at which times there are about 20 feet water at the Salt-house dock gates, and two feet more at the other dock gates.

The corporation make all necessary regulations relating to the docks; and the accounts of the receipt and expenditure are annually examined and published by commissioners unconnected with the corporation. Ships are here discharged by their own crews, but cooking on board is not permitted, and all lights must be put out at stated hours.

It cannot be doubted that the docks have greatly encouraged the increase which has taken place in the trade of Liverpool, and by their future enlargement, or the formation of additional ones, the port will readily accommodate the future increase of its commerce to any possible extent. In the year 1571, the inhabitants, addressing queen Elizabeth, styled the place the poor decayed town of Liverpool; and in fact, about that period it was only a little fishing town, having 12 barks, whose tonnage amounted to 223 tons, and which employed only 75 men. In the year 1805, the number of British built ships belonging to the port of Liverpool was 741, and their tonnage amounted to 111,227 tons: the tonnage of the ships which entered the docks in that year was 463,482 tons.

Statement of the amount of the dock duties at different periods: each year ending 24th. June.

Years.	Ships.	Duties. £.	s.	d.
1755	—	2,417	13	11
1760	1245	2,330	6	7
1765	1930	3,455	8	4
1770	2073	4,142	17	2
1775	2291	5 384	4	9
1780	2261	3,528	7	9
1785	3429	8,411	5	3
1790	4223	10,037	6	2½
1795	3948	9,368	16	4
1800	4746	23,379	13	6½
1805	4618	33,364	13	1
1808	5225	40,688	0	0

The tonnage of the ships which entered the docks in the year ending 24th June 1808, amounted to 516,836 tons.

London.—When it is considered that the port of London commands about three-fifths of the commerce of the whole kingdom, that it has frequently riding within it from 1300 to 1400 sail of vessels at a time, and in the course of the year about 14,000; that from the year 1700 to 1792 its imports had increased from 4,785,538 *l.* to 12,072,674 *l.* and its exports from 5,387,787 *l.* to 14,742,516 *l.*, it appears surprizing that proper accommodations for its commerce should have been so long wanting. The legal quays, which were only 1464 feet long, having remained the same as at the time of the fire of London, in the year 1666, were, with the aid of the sufferance wharfs, totally inadequate to the increase of its commerce. The inconveniences arising from the crowded state of the Thames at all times, but particularly at those periods when ships arrive in large fleets, were long felt and complained of by all the principal merchants; and from reference to the reports of committees, and other publications on the improvement of the port of London, it appears that different plans had been frequently suggested to extend the convenience of the legal quays both above and below London bridge. It was not, however, till the year 1793, that a plan was first projected for making wet docks for the port of London, in Wapping, the isle of Dogs, and at Rotherhithe, and the preference intended to have been given, in the first instance, to Wapping, from its vicinity to the city, the seat of business, and to the custom-house; one end of the spot fixed upon being within a quarter of a mile of the Tower of London, and the eastern extremity of it about one mile. The plan of docks meeting with approbation and encouragement, they were circulated generally to all the great leading interests in and out of parliament, and to all the principal persons connected with the commercial interest.

In 1794, a general meeting of merchants was convened, to consider the great inconveniences of the port of London, arising from the crowded state of the river, and the confined extent of the legal quays; when a committee was appointed to consider of the best mode of relief, who took into consideration all the plans which had been suggested, when they approved of the plan for making wet docks in Wapping with wharfs and warehouses on their borders, as the most effectual means of remedying the evils of the port. In consequence of this determination, Mr. Daniel Alexander, an ingenious architect and surveyor, who had been making great alterations at Rochester bridge, and who was conversant with operations connected with the tide, was directed to make a survey, and prepare plans and estimates for forming docks at Wapping, with the addition of a cut or canal leading to them, from that part of Blackwall where the present East India docks have been made, and along a line where the West India docks have been since formed. The plans and estimates were laid before a general meeting of merchants on 22d December, 1795, when they were unanimously approved, and a subscription of 800,000 *l.* was filled in a few hours, for carrying the same into execution. A committee was appointed to make application to parliament, who presented a petition in January 1796, which was referred to a select committee of the house of commons, who were directed "to enquire into the best mode of providing sufficient accommodation for the increased trade and shipping of the port of London."

The application of the merchants experienced great opposition both from the corporation of the city of London and from private interests; and a great variety of plans and projects were brought forward for the extension of the legal quays above and below the bridge, and the improvement of the river, with or without docks. This caused much delay, but the necessity of providing some additional accommodation for the increasing multitude of ships which filled the river became every day more evident; and, upon a comparison of the various plans for making docks in different situations, it was generally admitted, that wet docks might be formed in various situations at a much less expence than on the spot fixed upon for the London docks at Wap-

ping, but that the ſituation of the latter, from its vicinity to the ſeat of commerce, would much more than counterbalance the additional expence of their formation. Through the great exertions and perſeverance of William Vaughan, eſquire, aſſiſted by other highly reſpectable mercantile characters, the various obſtacles to the plan of the London docks were ſucceſſively overcome, and in Auguſt 1798, the ſubſcribers gave notice, that in the enſuing ſeſſion of parliament they meant to renew their application for forming docks at Wapping, and in December following they petitioned for leave to bring in a bill for this purpoſe. A few days after a petition was preſented by the corporation of London, with a view to ſimilar objects, and by making a navigable canal or paſſage acroſs the iſle of Dogs from Blackwall to Limehouſe, purchaſing the mooring-chains in the river, which were moſtly private property, and appointing harbour-maſters to regulate the navigating and mooring of veſſels in the port; they alſo propoſed to make wet docks in ſome part of the iſle of Dogs for the reception and diſcharge of Weſt India ſhipping. The latter part of the plan had however been taken up by a number of Weſt India merchants and planters, who had formed themſelves into a company diſtinct from the ſubſcribers to the London docks, for the purpoſe of forming docks for the reception of the Weſt India trade only, either alone, or in conjunction with the other improvements projected by the corporation. The general conviction of the neceſſity of ſome meaſure of this kind was not ſufficient to produce a union of intereſts in favour of either of the propoſed plans; at length the committee of the houſe of commons made a report, recommending the formation of wet docks as the only remedy for the evils of the port, and that they ſhould be made both at Wapping and the iſle of Dogs, but that the latter ſhould be adopted firſt.

The corporation of London and the Weſt India merchants forming a junction, the act for making the Weſt India docks paſſed in July 1799. In the next ſeſſion, on the 30th June 1800, an act was paſſed for forming the docks at Wapping, and another act has ſince been paſſed for making docks at Blackwall for the Eaſt India trade. Theſe ſeveral undertakings, all ariſing out of the original project of the London docks, have been ſince carried into execution, to the great convenience of the commerce of the port of London, and the permanent benefit of the ſubſcribers, by whom the large ſums neceſſary for accompliſhing them were advanced. For ſome particulars of the progreſs of their formation, ſee THAMES river, under the article CANALS.

Weſt India Docks.—The act for eſtabliſhing the Weſt India Dock Company, was paſſed 12th July 1799. Their original capital was 500,000*l.*, which they were impowered to increaſe to 600,000*l.* This capital was, however, found inſufficient for completing the undertaking, and in 1802 the company were authoriſed to add 200 000*l.* to it, making their capital 800,000*l.* which has been ſince increaſed to 1,200,000*l.* The dividends to be paid thereon to the ſubſcribers, are not to exceed 10 *per cent. per annum*, to which rate they have already attained.

The concerns of the company are under the management of twenty-one directors, eight of whom are choſen by the corporation of London, four of them being aldermen, and four common-council men.

The works were begun 2d February 1800, and the firſt ſhip entered the homeward-bound dock on 27th Auguſt 1802. The homeward-bound dock, ſee *Plate* N. *fig.* B. 1. which is 2600 feet long, and 500 feet broad, is eſtimated capable of holding 300 ſail of veſſels of 300 tons and upwards each. The outward-bound dock, B 2, is 2600 feet long, and 400 feet broad. They both communicate by means of locks at the end (next Blackwall) with a baſon of about ſix acres, with ſloping banks, which is connected with the river by the entrance lock; and at the end next Limehouſe, where there is another baſon of about two acres, built of brick, through which all veſſels go out, which have occaſion to go into the river to repair. The two docks are ſeparated and ſurrounded by ſtrong walls.

The uſe of theſe docks is limited to the Weſt India trade for 21 years. The company take the ſhips under their ſole direction, of unloading and management from the moment they enter the docks, diſcharging the ſame by their own ſervants; when the crews are diſmiſſed, and neither cooking nor reſidence allowed on board any of the veſſels while they remain in the homeward-bound docks, the gates of which are ſhut every evening at ſtated hours. A military guard is ſtationed without the docks day and night. The diſtance from the ſtandard in Cornhill, to the neareſt dock gates, is rather more than three miles, and to the further extremity of the dock wall, about half a mile more; a conſiderable expence of cartage is unavoidably incurred, by the ſhips diſcharging at this diſtance, but there is an excellent road both to theſe docks, and to the Eaſt India docks.

Both the docks and warehouſes are handſome and ſpacious, the whole forming a noble and intereſting object, which muſt impreſs every one with an idea of the vaſt magnitude of the branch of commerce, to which they are appropriated. The warehouſes on the north and weſt ſides, are ten in number, with partition walls up to, but not through the roof, and are capable of containing 8000 hogſheads of ſugar each; on the ſouth ſide are extenſive warehouſes for rum. The docks were planned and executed by William Jeſſop, eſq. civil engineer, and the warehouſes by Mr. Gwylt, ſurveyor and architect.

Under the Weſt India dock act, the corporation of London were empowered to make a canal from Limehouſe to Blackwall, of about three quarters of a mile in length, to ſave the navigation round the Iſle of Dogs, which has been completed, and may probably at ſome future period be converted into a dock. See *Plate of Docks*, *fig.* D.

London Docks.—The act for eſtabliſhing this company was paſſed 20th June 1800. Their original capital ſtock was 1,200 000*l.*, and they were authoriſed to borrow, at intereſt, the further ſum of 300,000*l.*; but a larger capital being found neceſſary for completing the undertaking, they applied to parliament, in 1804, for leave to augment their capital ſtock by 500,000*l.*; and having ſince obtained another act for the liberty of raiſing a further ſum of 500,000*l.*, the total capital ſtock the company are now authoriſed to raiſe, if it ſhall be found neceſſary, is 2,200,000*l.* The dividends to be paid thereon to the ſubſcribers, are limited to 10 *per cent. per annum.* The management is veſted in 24 directors, elected annually, of whom the lord mayor is one.

The original plan of theſe docks (with the canal, which had been abandoned) was ſubmitted by the directors to the conſideration of four civil engineers of the firſt eminence and reſpectability, *viz.* Meſſrs. Robert Mylne, John Rennie, Joſeph Huddart, and William Chapman, and underwent ſome alterations by them. The dock and baſon, as altered by them, were then executed under the direction of Mr. Rennie, and the warehouſes and wall by Mr. Alexander.

The dock, baſon, and warehouſes, which are compleated, are of brick and ſtone, are well deſigned, in a chaſte and grand ſtyle, and happily executed, producing a noble effect. The length of the dock, as in *Plate of Docks*, *fig.* A. 1. is 1260 feet long, and 690 feet broad, containing 20 acres, and the baſon marked A. 2. as three acres, and the whole capable of containing about 230 ſhips of 300 tons burthen and upwards.

In the act a power was preserved to make a second dock and bason to the eastward, with an entrance at Shadwell, containing an area of 14 acres, as denoted in the plan marked A 3 and 4. There are at present, on the north side of the dock, five stacks of warehouses furnished with party and cross sub-divisionary walls through the roofs, as a further protection against fire. On the south side are other warehouses, besides vacant spaces left in different parts of the premises for additional warehouses. On the east side is the tobacco warehouse, planned to contain 24,000 hogsheads of tobacco, and spacious arched vaults underneath for wine and tobacco. The latter are now wholly appropriated to wine, and hold many thousand pipes. The whole building stands upon an area of near five acres, covering more ground, under one roof, than any public building or undertaking, except the pyramids of Egypt. Its roof is light, airy, and simple, and adds greatly to the beauty and boldness of the design, and stands unrivalled in architectural buildings of its kind.

The company was required to complete the docks within seven years, which was afterwards extended to twelve years. On the 24th January 1805, they gave notice, by advertisement, that the bason at Bel.-dock, and the dock communicating therewith, and also part of the warehouses, vaults, and quays, were ready for the reception of ships and landing their cargoes, in consequence of which the dock was opened for public use in the following week.

All ships laden with wine, brandy, geneva, and other spirits, tobacco, and rice, must unload in these docks for the term of twenty-one years; with all other vessels the use of the docks is optional, excepting those from the East and West Indies. The ships discharge their cargoes under the company's cranes, by their own crews. In these docks, cooking and residence on board are allowed, but no lights are permitted after certain hours. The whole is surrounded by a wall, the gates of which are shut at stated hours.

There is a neat swivel cast-iron bridge over the entrance lock at Wapping, and an excellent double steam-engine erected, which was used while the docks were making, to carry off the water; it is not now worked.

The rise of the tide at the entrance lock of the bason, is four feet lower than the dock itself.

East India Docks.—The act for establishing the company passed 27th July 1803. Their original capital was 200,000*l.* divided into shares of 100*l.* each; and they were authorized to increase the capital to 300,000*l.* if it should be found necessary. In 1806 they were impowered to add 100,000*l.* more to their capital, making with the former sum 400,000*l.*, nearly the whole of which has been raised. The dividends to be paid thereon to the subscribers, are, as in the two preceding companies, limited to 10 *per cent. per annum.* The concern is under the management of 13 directors, who must be holders of at least 20 shares of the company's stock, and four of them must be directors of the East India company.

The first stone of these docks was laid in March 1805, and the first ship entered them in August 1806. The dimensions of the dock for unloading inwards are 1410 feet in length, and 560 feet in width, containing about $18\frac{1}{8}$ acres: the dock for loading outwards, which was a part of Mr. Perry's dock, is 780 feet in length, and 520 feet in width, containing $9\frac{1}{4}$ acres. The extent of the entrance bason, which connects them with the river, is $2\frac{3}{4}$ acres; the length of the entrance lock 210 feet, the width of the gates 48 feet in the clear, and the depth of water at ordinary spring-tides 24 feet. See *Plate* N. C. 1. 2.

These docks are appropriated solely to the reception of East India shipping, and the company undertake to deliver the whole of the cargoes. No cooking, fire, or residence on board, are permitted in these docks, the gates of which are shut every afternoon at four o'clock. The distance from the East India warehouses being about four miles, the goods are conveyed thither in caravans of a particular construction, by an excellent road, towards the formation of which 10,000*l.* was contributed by the company.

Perry's Dock at Blackwall, and *Greenland Dock* on the opposite side of the river, were private property, having been formed by enterprising individuals, long before any public accommodation of this kind existed in the port of London. The first now forms one of the East India docks; and Greenland dock, hitherto appropriated to the purposes of the whale fishery, has likewise been purchased by a company.

The Surrey canal company have a dock at the entrance of their canal for small vessels, and have raised a considerable capital.

It affords a striking proof of the wealth and prosperity of the city of London to find, that in the course of about ten years, there has been expended a capital of between four and five millions in these great undertakings for providing accommodation and security to its shipping and commerce.

Hull Dock, is situated on the Humber, and was formed under the authority of an act passed in 1774. It is about 480 yards long, and 88 yards wide, containing nearly 10 acres, and will accommodate about 130 vessels at a time. The original capital of the company consisted of 120 shares, which have since been increased to 180 shares. It has been a most profitable concern to the subscribers, as they have usually made a large dividend; this, however, has varied very considerably: in the year 1806 they divided 72*l.* 15*s.* 10*d.* *per* share; but in 1807, after having admitted 25 new shares, the dividend was only 49*l.* 9*s.* 1*d.* *per* share. The formation of another dock, with other improvements, has been undertaken.

Bristol.—Bristol, with a large trade carried on in an inconvenient harbour from the great height of its tides, has, at length, undertaken an extensive plan, according to which a very capacious wet dock is to be formed by damming up the river Avon for about two miles of its length, and turning the river into a new cut which has been formed to receive it.

Other ports, such as Lancaster, Grimsby, Dover, and Margate, &c. have their docks or piers for the safety and accommodation of the shipping frequenting them.

At *Leith*, in Scotland, a large range of docks are making on an extensive scale, which are to be capable of receiving the men of war which may frequent that part of the coast, the old harbour having been found very inadequate: one of the docks is already completed, and a dry dock is nearly so. From Leith being within one mile of Edinburgh, and the spirit of improvement prevailing in Scotland, there is every probability of these docks and the intended inclosed harbour being executed on an extensive and judicious plan, and becoming of much public utility.

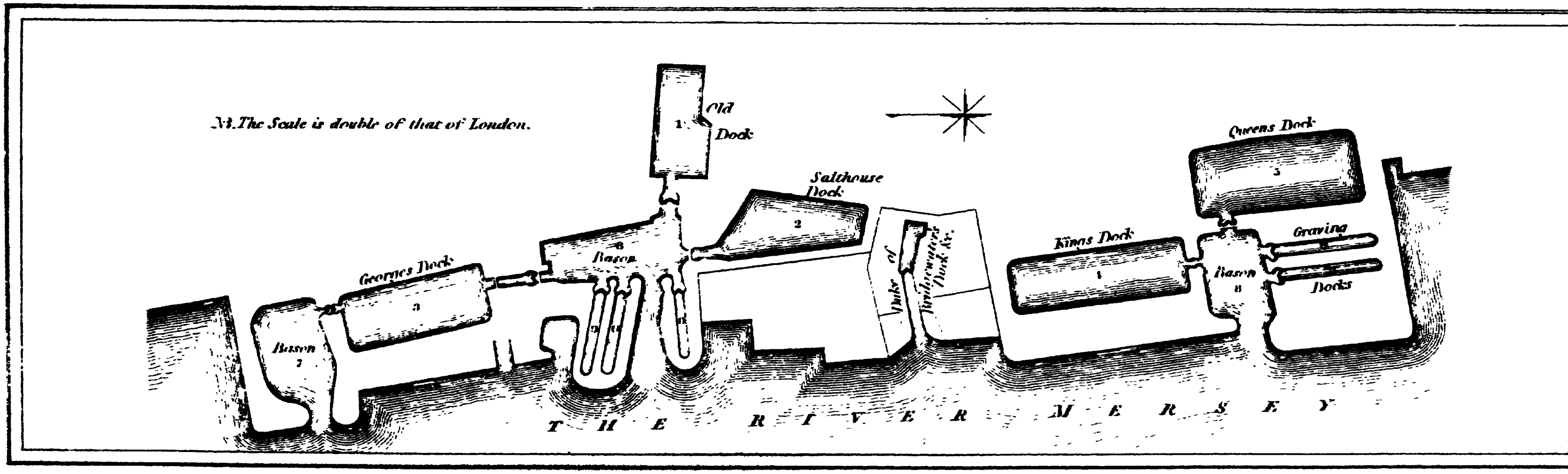
On the continent, several ports, such as Havre, Ostend, &c. have wet docks on an extensive scale, under various regulations.

Dock-*Yards*, are magazines of all sorts of naval store, and timber for ship building; the royal dock-yards in England, are those at Chatham, Portsmouth, Plymouth, Woolwich, Deptford, and Sheerness. In time of peace, ships of war are laid up in these docks, those of the first rates mostly at Chatham, where, and at other yards, they receive, from time to time, such repairs as are necessary.

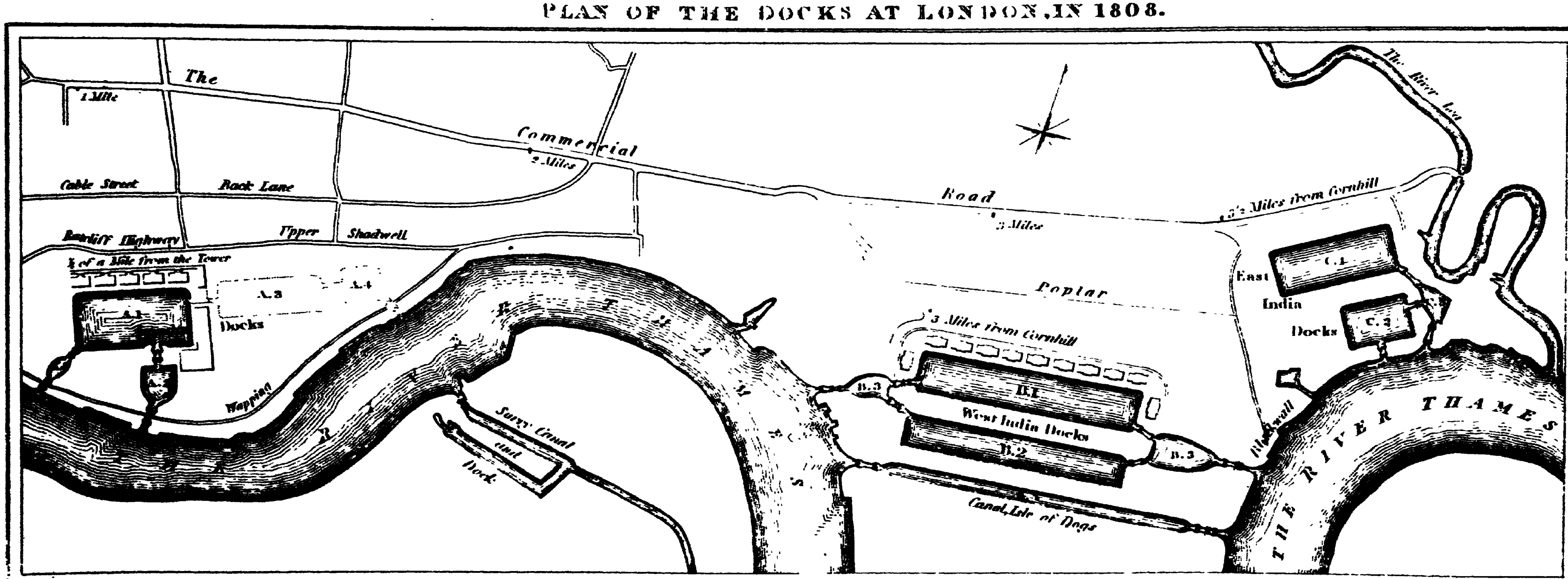
Thefe yards are generally fupplied from the northern crowns, with hemp, pitch, tar, rofin, canvas, oak-plank, and feveral other fpecies. But as for mafts, particularly thofe of the largeft fize, they have been ufually brought from New England.

The principal dock-yards are governed by a commiffioner, refident at the port, who fuperintends all the mufters of the officers, artificers and labourers, employed in the dock-yard and ordinary. He alfo controuls their payments; examines the accounts; contracts and draws bills on the navy-office to fupply the deficiency of ftores, and regulates whatever belongs to the yard, maintaining due order in the refpective offices.

PLAN OF THE DOCKS AT LIVERPOOL, IN 1808.



PLAN OF THE DOCKS AT LONDON, IN 1808.



Published June 2nd 1809 by Longman Hurst Rees and Orme Paternoster Row, London.

Engraved by Wilson Lowry

Draught

DRAUGHT, in *Architecture*, is the reprefentation of a building delineated on paper, explaining the various parts of the exterior and interior by means of plans, elevations, and fections drawn to a fcale, by which all the parts are reprefented on a plane in the fame proportions of the different fides of the intended edifice, or, at leaft, the proportions may be afcertained from thefe drawings. The extent of the building, with regard to its horizontal dimenfions, is afcertained by means of plans. The dimenfions of the vertical faces are generally obtained by the elevations and fections, and always when the plane of delineation is parallel to thefe faces. The vertical dimenfions of buildings, upon circular and polygonal plans, muft be found partly from the plans, and partly from the elevations or fections. Over and above general plans, elevations, and fections in complex buildings, a fet of drawings, fhewing the detail of the fmaller parts, will be neceffary.

Befides thefe drawings, which are ufed in the conducting of the work, perfpective reprefentations for the ufe of the proprietor will alfo be neceffary, in order that he may form a juft idea of the edifice which he intends to rear in one or more points of view.

When the feveral ftories of a building differ in their conftruction, each ftory requires a feparate plan. The fection is generally taken, parallel to one of the fides of the edifice, through the moft complex part of it. In this the ftair-cafe is commonly fhewn. Moft buildings require, at leaft, two fections; fome many more. When the fides of a building are diffimilar, as many elevations will be required as there are fides.

The number, the form, and the difpofitions of rooms, are fhewn by the plans.

He who gives the feveral defigns of a building ought to be well acquainted with the nature of its fabrication, or of conftruction in general, before he commits his ideas to paper, and to the examination of the public, or otherwife he will be liable to cenfure.

DRAUGHT-*Horfe*. See HORSE.

DRAUGHT, in *Mechanics*, the force or power neceffary to move any machine, as a horfe-mill, waggon, cart, plough, &c. For accurately and conveniently afcertaining the draught of (or power exerted by) horfes, oxen, men, &c. in drawing, as alfo for determining the direct pull or ftrain on any rope, chain, &c., various machines have been invented, fome of which we propofe to defcribe under the article DYNAMOMETER, which fee.

DRAUGHT, in *Medicine*. See POTION.

DRAUGHT, in *Painting*, &c. See DESIGN.

DRAUGHT, in *Trade*, is an allowance made in the weight of commodities; the fame as clough.

DRAUGHT, is alfo ufed fometimes for a bill of exchange, and commonly for an order for the payment of any fum of money, due, &c. Then the perfon who gives the order is faid to draw upon the other.

DRAUGHT, *reduction of a*. See REDUCTION, and PENTAGRAPH.

DRAUGHT-*Compaffes*, thofe provided with feveral moveable points, to draw fine draughts in architecture, &c. See COMPASS.

DRAUGHT *and Cording of Looms*, fignifies, among *Weavers*, the art of adapting thofe parts of a loom which move the warp, to the formation of various kinds of ornamental figures upon cloth. In every fpecies of weaving, whether direct or crofs, the whole difference of pattern or effect is produced, either by the fucceffion in which the threads of warp are in-

troduced into the heddles, or by the succession in which those heddles are moved in the working. The heddles being stretched between two shafts of wood, all the heddles connected by the same shafts are called a leaf, and as the operation of introducing the warp into any number of leaves is called drawing a warp, the plan of succession is called the draught. When this operation has been performed correctly, the next part of the weaver's business is to connect the different leaves with the levers or treddles by which they are to be moved, so that one or more may be raised or sunk by every treddle successively, as may be required to effect the pattern required. These connections being made by coupling the different parts of the apparatus by cords, this operation is called the cording. In order to direct the operator in this part of his business, especially if previously unacquainted with the particular pattern upon which he is employed, plans are drawn upon paper, specimens of which will be found in *Plate* XII. *Miscellany*. These plans are horizontal sections of a loom, the heddles being represented across the paper at A, and the treddles under them, and crossing them at right angles at B. In *figs.* 1 and 2, they are represented as distinct pieces of wood, those across being the under shaft of each leaf of heddles, and those at the left hand the treddles. In actual weaving, the treddles are placed at right-angles to the heddles, the sinking cords descending perpendicularly, as nearly as possible, to the centre of the latter. Placing them at the left hand therefore, is only for ready inspection, and for practical convenience. At C, a few threads of warp are shewn as they pass through the heddles, and the marks denote the leaf with which each thread is connected. Thus in *fig.* 1, the right-hand thread, next to A, passes through the eye of a heddle upon the back leaf, and is disconnected with all the other leaves; the next thread passes through a heddle on the second leaf; the third through the third leaf; the fourth through the fourth leaf, and the fifth through the fifth or front leaf. One set of the draught being now compleated, the weaver again begins with the back leaf, and proceeds in the same succession again to the front. Two sets of the draught are represented in this figure, and the same succession, it is understood by weavers, (who seldom draw more than one set,) must be repeated until all the warp is included. When they proceed to apply the cords, the left hand part of the plan at B serves as a guide. In all the plans upon this plate, excepting one which shall be noticed, a connection must be formed by cording between every leaf of heddles and every treddle; for all the leaves must either rise or sink. The raising motion is effected by coupling the leaf to one end of its correspondent top lever; the other end of this lever is tied to the long march below, and this to the treddle. The sinking connection is carried directly from under the leaf to the treddle. To direct a weaver which of these connections is to be formed with each treddle, a black spot is placed when a leaf is to be raised, where the leaf and treddle intersect each other upon the plan, and the sinking connections are left blank. For example, to cord the treddle 1. To the back leaf put a raising cord, and to each of the other four sinking cords. For the treddle 2, raise the second leaf, and sink the remaining four, and so of the rest; the spot always denoting the leaf or leaves to be raised. The *figs.* 1 and 2 are drawn for the purpose of rendering the general principle of this kind of plans familiar to those who have not been previously acquainted with them; but those, who have been accustomed to manufacture and weave ornamented cloths, never consume time by representing either heddles or treddles as solid or distinct bodies. They content themselves with ruling a number of lines across a piece of paper, sufficient to make the intervals between these lines represent the number of leaves required. Upon these intervals, they merely mark the succession of the draught, without producing every line to resemble a thread of warp. At the left-hand they draw as many lines across the former as will afford an interval for each treddle, and in the squares, produced by the intersections of these lines, they place the dots, spots, or cyphers, which denote the raising cords. It is also common to continue the cross lines, which denote the treddles a considerable length beyond the intersections, and to mark, by dots, placed diagonally in the intervals, the order or succession in which the treddles are to be pressed down in weaving. The former of these modes has been adopted in the remaining plan, upon the plate, but to save room the latter has been avoided, and the succession marked by the order of the figures under the intervals which denote the treddles.

Some explanation of the various kinds of fanciful cloths, represented by these plans, may serve further to illustrate this subject, which is, perhaps, the most important of any connected with the manufacture of cloth, and will also enable a person, who thoroughly studies them, readily to acquire a competent knowledge of the other varieties in weaving, which are boundless. *Figs.* 1 and 2 represent the draught and cording of the two varieties of tweeled cloth wrought with five leaves of heddles. The first is the regular or run tweel, which, as every leaf rises in regular succession, while the rest are sunk, interweaves the warp and woof only at every fifth interval, and as the succession is uniform, the cloth, when woven, presents the appearance of parallel diagonal lines, at an angle of about 45° over the whole surface. When there is no other figure upon the cloth, and the fabric is fine, this produces a very pleasing effect, and is much used, especially in the manufacture of silks of various descriptions. Tweeling is also much employed in the coarser descriptions of cloths made from every kind of material employed in the manufacture. In the linen, it is used for sheeting and many other kinds of household cloths which require durability. Many of the stronger kinds of woollen cloths are also tweeled. Goods are manufactured in very great variety in Lancashire from cotton, and many kinds of fanciful tweeling introduced. A tweel may have the regularity of its diagonal lines broken, by applying the cording as in *fig.* 2. It will be observed, that in both figures the draught of the warp is precisely the same, and that the whole difference of the two plans consists in the order of placing the spots denoting the raising cords, the first being regular and successive, the second alternate.

Figs. 3 and 4 are the regular and broken tweels which may be produced with eight leaves. This properly is the tweel denominated sattin in the silk manufacture, although many webs of silk, wrought with only five leaves, receive that appellation. Some of the finest Florentine silks are tweeled with sixteen leaves. When the broken tweel of eight leaves is used, the effect is much superior to what could be produced by a smaller number, for in this two leaves are passed in every interval, which gives a much nearer resemblance to plain cloth than the others. For this reason it is preferred in weaving the finest damasks. The draught of the eight leaf tweel differs in nothing from the others, excepting in the number of leaves. The difference of the cording in the broken tweel will appear by inspecting the cyphers which mark the raising cords, and comparing them with those of the broken tweel of five leaves. *Fig.* 5. represents the draught and cording of striped dimity of a tweel of five leaves. This is the most simple species of fanciful tweeling. It consists of ten leaves, or double the number of the common tweel. These ten leaves are moved by only five treddles in

the ſame manner as a common tweel. The ſtripe is formed by one ſet of the leaves fluſhing the warp, and the other ſet the woof. The *fig.* in the *Plate* repreſents a ſtripe formed by ten threads, alternately drawn through each of the two ſets of leaves. In this caſe, the ſtripe and the intervals will be equally broad, and what is the ſtripe upon one ſide of the cloth, will be the interval upon the other, and *vice verſâ*. But great variety of patterns may be introduced by drawing the warp in greater or ſmaller portions through either ſet. The tweel is of the regular kind, but may be broken, by placing the cording as in *fig.* 2. It will be obſerved that the cording marks of the lower or front leaves, are exactly the converſe of the other ſet; for where a raiſing mark is placed upon one, it is marked for ſinking in the other: that is to ſay, the mark is omitted; and all leaves which ſink in the one, are marked for raiſing in the other: thus one thread riſes in ſucceſſion in the back ſet and four ſink, but in the front ſet four riſe and only one ſinks. The woof, of courſe, paſſing over the four ſunk threads, and under the raiſed one, in the firſt inſtance, is fluſhed above; but where the reverſe takes place, as in the ſecond, it is fluſhed below, and thus the appearance of a ſtripe is formed. The analogy ſubſiſting between ſtriped dimity and dornock is ſo great, that before noticing the plan for fancy dimity, it may be proper to allude to the dornock, the plan of which is repreſented by *fig.* 6.

The draught of dornock is preciſely the ſame, in every reſpect, with that of ſtriped dimity. It alſo conſiſts of two ſets of tweeling heddles, whether three, four, or five leaves, are uſed for each ſet. The left hand ſet of treddles is alſo corded exactly in the ſame way, as will appear by comparing them. But, as the dimity is a continued ſtripe from the beginning to the end of the web, only five treddles are required to move ten leaves. The dornock, being checkerwork, the weaver muſt poſſeſs the power of reverſing this at pleaſure. He therefore adds five more treddles, the cording of which is exactly the reverſe of the former; that is to ſay, the back leaves in the former caſe having one leaf raiſed and four ſunk, have, by working with theſe additional treddles, one leaf ſunk and four leaves raiſed. The front leaves are in the ſame manner reverſed, and the mounting is compleat. So long as the weaver continues to work with either ſet, a ſtripe will be formed as in the dimity, but when he changes his feet from one ſet to the other, the whole effect is reverſed, and the checkers formed. The dornock pattern upon the deſign paper, *Plate* A, may be thus explained: let every ſquare of the deſign repreſent five threads upon either ſet of heddles, which are ſaid by weavers to be once over the draught, ſuppoſing the tweel to be one of five leaves: draw three parallel lines, as under, to form two intervals, each repreſenting one of the ſets: the draught will then be as follows:—

The above is exactly ſo much of the pattern as is there laid down, to ſhew its appearance, but one whole range of the pattern is compleated by the figure 1 neareſt to the right hand upon the lower interval between the lines, and the remaining figures nearer to the right form the beginning of a ſecond range or ſet. Theſe are to be repeated in the ſame way acroſs the whole warp. The lower interval repreſents the five front leaves; the upper interval the five back ones. The firſt figure 4 denotes that five threads are to be ſucceſſively drawn upon the back leaves, and this operation repeated four times. The firſt figure 4 in the lower interval expreſſes that the ſame is to be done upon the front leaves, and each figure, by its diagonal poſition, ſhews how often, and in what ſucceſſion five threads are to be drawn upon the leaves, which the interval in which it is placed repreſents.

Dornocks of more extenſive patterns are ſometimes woven with 3, 4, 5, and even 6 ſets of leaves; but after the leaves exceed 15 in number, they both occupy an inconvenient ſpace, and are very unwieldy to work. For theſe reaſons the diaper harneſs is in almoſt every inſtance preferred.

Fig. 7, repreſents the draught and cording of a fanciful ſpecies of dimity, which has been manufactured to great extent, although the prevalent taſte for ſimplicity of pattern of the preſent day has rendered it leſs an object of demand than formerly. In this plan it will be obſerved, that the warp is not drawn directly from the back to the front leaf as in the former examples, but when it has arrived at either external leaf, the draught is reverſed, and returns gradually to the other. The ſame draught is frequently uſed in tweeling, when it is wiſhed that the diagonal lines ſhould appear upon the cloth in a zig-zag direction. This plan exhibits the draught and cording, which will produce the pattern upon the deſign paper in *Plate* A. Were all the ſquares produced by the interſection of the lines denoting the leaves and treddles, where the raiſed dots are placed, filled the ſame as on the deſign, they would produce the effect of exactly one-fourth of that pattern. This is cauſed by the reverſing of the draught, which gives the other ſide reverſed as on the deſign. and when all the treddles, from 1 to 16, have been ſucceſſively uſed in the working, one-half of the pattern will be complete. The weaver then goes again over his treddles in the reverſed order of the numbers, from 17 to 30, when the other half of the pattern will be completed. From this ſimilarity of the cording to the deſign, it is eaſy, when a deſign is given, to make out the draught and cording proper to work it, and when the cording is given to ſee its effect upon the deſign.

Fig. 8, repreſents the draught of the diaper mounting, and the cording of the front leaves, which are moved by treddles. The mounting, which raiſes the leaves of the harneſs, muſt be taken from the deſign paper, in a way ſimilar to that uſed for the draw loom, and as deſcribed in that article. From the plan it will appear, that five threads are included in every mail of the harneſs, and that theſe are drawn in ſingle threads through the front leaves, as deſcribed in the article Diaper. The cording forms an exception to the general rule, that when one or more leaves are raiſed, all the reſt muſt be ſunk, for in this inſtance one leaf riſes, one ſinks, and three remain ſtationary. An additional mark, therefore, is uſed in this plan. The dots, as formerly, denote raiſing cords, the blanks ſinking cords, and where the cord is to be totally omitted the croſs marks × are placed.

Fig. 9, is the draught and cording of a ſpot whoſe two ſides are ſimilar, but reverſed. That upon the plan forms a diamond, ſimilar to the one drawn upon the deſign paper, *Plate* A, but ſmaller in ſize. The draught here is reverſed, as in the dimity plan, and the treading is alſo to be reverſed after arriving at 6, to complete the diamond. Like it too, the raiſing marks form one-fourth of the pattern. In weaving ſpots, they are commonly placed at intervals, with a portion of plain cloth between them, and are generally placed in alternate rows, the ſpots of one row being between thoſe of the other. But as intervals of plain cloth muſt take place, both by the warp and woof, two leaves are added for that purpoſe. The front, or ground leaf, includes every ſecond thread of the whole warp. The ſecond, or plain leaf, that part which forms the intervals by the warp. The

remaining leaves form the ſpots; the firſt ſix being allotted to one row of ſpots, and the ſecond ſix to the next row, where each ſpot is in the centre between the former. The reverſed draught of the firſt is ſhewn entire, and is ſucceeded by twelve threads of plain. One-half of the draught of the next row is then given, which is to be completed exactly like the firſt, and ſucceeded by twelve threads more of plain, when one ſet of the pattern being finiſhed, the ſame ſucceſſion is to be repeated over the whole warp. As ſpots are formed by inſerting woof of coarſer dimenſions than that which forms the fabric, every ſecond thread only is allotted for the ſpotting. Thoſe included in the front, or ground leaf, are therefore repreſented by lines, and the ſpot threads between them by marks in the intervals, as in the other plans.

The treddles neceſſary to work this ſpot are in number fourteen. Of theſe, the two in the centre, A, B, when preſſed alternately, will produce plain cloth, for B raiſes the front leaf, which includes half of the warp, and ſinks all the reſt, while A exactly reverſes the operation. The ſpot-treddles, on the left-hand, work the row contained in the firſt ſix ſpot-leaves, and thoſe upon the right-hand the row contained in the ſecond ſix. In working ſpots, one thread, or ſhot of ſpotting-woof, and two of plain, are ſucceſſively inſerted by means of two ſeparate ſhuttles.

Diſſimilar ſpots are thoſe whoſe ſides are quite different from each other. The draught only of theſe is repreſented by *fig.* 10. The cording depends entirely upon the figure, and may be ſupplied by the following ſimple rule: Having ruled the lines which repreſent the heddles, and croſſed them by thoſe repreſenting the treddles, ſquares will be formed ſimilar to thoſe upon deſign-paper. The pattern being drawn upon deſign-paper, let the lines denoting the heddles repreſent the lines of the deſign, from top to bottom of the paper, and the treddle-lines the croſs-lines. Place a raiſing-dot for every ſquare which is coloured on the deſign, and the plan of cording will be correct. It is neceſſary, however, to remark, that when more than one ſquare is included between the ſame parallel-lines, from top to bottom of the deſign, it is needleſs to transfer it more than once to the cording plan, for the treddle, being once marked, will repeat the operation as often as it is preſſed, and, therefore, more than one treddle, for the ſame operation, would only load the loom with uſeleſs and cumbrous machinery. The plain leaves and additional leaves, for placing one row in the boſom of another, are quite the ſame in ſpots, whether ſimilar or diſſimilar. There is, indeed, a ſpot called a paper-ſpot, where all the warp is upon ſpot-leaves, except the intervals, and every ſecond thread of woof is then coarſe. It is undoubtedly ſuperior in effect to the common ſpot; but, as it requires nearly twice the mounting, it is very expenſive, and, therefore, little uſed. Some very beautiful ſpecimens of it are occaſionally imported from India.

Draw-loom

DRAW-*loom* is the moſt complicated and extenſive machine, in its operation, uſed in the weaving of ornamented cloth. There is no diverſity of pattern, or figure, however extenſive, which can be brought within the whole range of cloth of the largeſt dimenſions, but may be produced by this uſeful, although expenſive, machine. Draw-looms, in Britain, are uſed for three purpoſes, *viz.* for weaving damaſk, carpets, and the moſt extenſive patterns of ſpotted muſlins. The general principle of all theſe machines is pretty ſimilar, but modifications in their conſtruction take place, according to the particular purpoſes for which they are intended. When patterns become ſo extenſive, that the number of heddles neceſſary for moving the warp in its numerous combinations, could neither be included within any moderate bounds, nor worked by any moderate power, it becomes neceſſary to have recourſe to the draw-loom. Of all the draw-looms, that for weaving fine damaſk is the moſt extenſive; ſome of thoſe in common uſe containing upwards of 120 deſigns, of 10 ſpaces each, which renders them equal to 1200 leaves of the diaper harneſs, or 6000 of the leaves uſed for dornock, dimity, or common tweeling. The general principle of the draw-loom harneſs, and the mode by which the fluſhing is reverſed, is in every reſpect the ſame with that of the diaper, the difference conſiſting ſolely in the ſuperior extent of the former, and the method of mounting and working it. *Fig.* 3. *Plate* XIV. *Miſcellany*, is a perſpective view of the harneſs part of a draw-loom, and the apparatus for working it. The number of harneſs-cords of a draw-loom is ſo great, and they are of neceſſity ſo cloſely crowded together, that any repreſentation of the whole, even if drawn upon a very large ſcale, muſt convey a very inadequate idea of their conſtruction and operation. A few, therefore, only are repreſented at intervals to illuſtrate the way of conſtructing them, and this being once well underſtood, may be extended to any length that conveniency will admit. The harneſs of the draw-loom is not confined by leaves, but every cord carrying a mail for the warp is kept ſtretched by a weight. The mails are the ſame as thoſe of the diaper, *fig.* 2. *Plate* XIV. The weights attached to the harneſs are repreſented at L. A horizontal board, or frame C, is fixed acroſs the loom, and is either perforated with a number of ſmall holes, or divided by wires, or pins, to ſerve as guides to the cords of the harneſs paſſing through them. When the range, or extent of the deſign, has been aſcertained, by counting on the paper the greateſt number of ſquares contained in it from right to left, the harneſs muſt be made to correſpond with this range. Let the range be ſuppoſed to extend to 500 ſquares, and the whole breadth of the warp to contain 10,000 threads. If five threads are to be drawn through each mail, the number of mails compoſing the harneſs will be 2000, and four ranges of the pattern will include the whole breadth. The diviſions in the board C, and the number of pullies in the box, or caſe H, being adapted to this, the operator may proceed to put up his harneſs, which is done as follows: the 1ſt, 501ſt, 1001ſt, and 1501ſt harneſs twines, after being paſſed through their reſpective intervals in the board, or frame C, are to be knotted together at M. A cord being attached to theſe is carried over the firſt pulley in the caſe H, and is made faſt to the piece of wood G, which is generally called the *table*. The 2d, 502d, 1002d, and 1502d, are connected in the ſame way, and the cord attached to them, paſſing over the ſecond pulley, is faſtened to the table as before. The ſame operation is ſucceſſively repeated, until the whole 500 connections are compleated. The cords at B, paſſing over the pullies and faſtened to the table, are called the *tail* of the harneſs. From each cord in the tail a vertical cord deſcends, and is made faſt to a piece of wood K, which is laſhed to a fixture in the floor. Theſe cords, repreſented at D, are called *ſimples*. The draught of the warp through the mails of the harneſs is regularly progreſſive from right to left, as in common tweeling, and the draught, cording, and mounting of the front leaves are exactly the ſame as in diaper. A ſtout perpendicular cord is now ſtretched from the roof to the floor, and made faſt at both ends. This cord is repreſented at I, and the loom is then ready to be adapted to work any pattern, of the range of 500 ſquares, or mails.

The next operation, therefore, is to apply a certain number of ſmall cords, called *laſhes*, and repreſented at E, ſo as to form the particular pattern required. This is called reading on the deſign, and from the complexity of the operation, and the neceſſity of its being accurately done, is performed by two perſons. The firſt of theſe perſons ſelects from the deſign paper the ſimples, to which laſhes are to be ſucceſſively applied; and it is the buſineſs of the ſecond to apply thoſe laſhes according to the inſtructions which he receives from the firſt. To read or ſelect the laſhes in their proper rotation, it is proper to obſerve, that the whole range of ſquares, from right to left, between the extreme points of the pattern, is equal to the whole number of ſimples, and the whole range from top to bottom, to the number of operations which thoſe ſimples are to undergo. The perſon who is to ſelect, therefore, taking the deſign paper, begins

at the loweft fquare, and counting from the right hand, inftructs the other to pafs as many fimples as there are blank fquares upon the paper, to put lafhes to as many as are coloured, again to pafs the blanks, take the coloured fquares, and fo on until he has reached the left fide of the pattern. When thefe lafhes have been applied, which is done by paffing each loofely round the fimples which it is to work, they are knotted together, and attached to the cord I by a loop, fo that they may flide up and down freely, both upon the cord and the fimples. Proceeding to the fecond fquare from the bottom, the felection is made in the fame way, and thus they continue until they have reached the top. The lafhes being now in clufters upon the cord I, thefe clufters are connected at convenient diftances from each other, by fmall cords reprefented at F, the firft applied clufter being loweft upon the cord I.

The draw-loom being ready for work, the operators may begin to weave. Two perfons are required to work the loom. One of thefe pulls down the firft fet of lafhes, the whole being placed high upon the cord I, and by pulling them tight, draws the fimples with which they are connected clear of all the reft. Then by grafping thefe fimples firmly in his hand, and pulling them down, he tightens the tail cords at B, by making them diverge more from a ftraight line, and of courfe raifes the mails which are attached to them by the harnefs twines at M. The weaver then works over his front, mounting, as in common tweeling, once, or oftener, if more fquares than one, upon the defign, are included between the fame parallel ftraight lines from top to bottom. When a change of the harnefs becomes neceffary, the connecting cord F pulls down the fecond clufter of lafhes, upon which the fame operation is performed as before. By thefe means, the fimples, however numerous, (and in the cafe we have fuppofed they would amount to 500,) are felected from each other with the utmoft accuracy and facility. The fucceffive repetition of the fame operation compleats the pattern, and then it is only neceffary to pufh the lafhes up again, and begin a new one.

When the mounting of the draw-loom is very extenfive, it would be inconvenient to ufe only one cafe of pullies; for the tail-cords and the frame of this cafe muft be extended to very inconvenient dimenfions. Befides this, when fo many pullies are employed, the tail-cords muft deviate fo much from the perpendicular line, that there would be much danger of throwing the cords off the pullies, and fetting the machine faft until each cord was replaced. Indeed, to prevent the danger of this, which materially impedes the operation, it is cuftomary to place guides of wire under the pullies, to confine the cords. But when the mounting is very extenfive, two, and fometimes three, cafes of pullies are very generally ufed. Thefe are placed parallel to each other, that reprefented at H being the middle one, and an equal number of tail cords are conducted over each. It is alfo ufual to conftruct more than one fet of fimples, that which is to be ufed being lafhed to the floor, while the others are loofe and hung near the roof, until it becomes neceffary to ufe them in their turns. This, indeed, is very ufeful in working bordered table-cloths, where the whole is frequently the continuation of one defign, extending fometimes three yards, or more, in breadth, and five or fix yards in length.

In an age like the prefent, when fimplification of procefs and faving of labour have become objects of fuch general attention, it is not wonderful that plans, which have thefe for their object, fhould have been adapted to the draw-loom as well as to other machinery. One of thefe, lately introduced at Dunfermline, has been pretty generally adopted, and appears, upon the whole, to have given very confiderable fatisfaction. Whether properly or not, it is there known by the name of the patent draw-loom.

The object of the patent draw-loom is, to enable the weaver to change his harnefs, as well as to perform the other neceffary operations of weaving, and confequently to fuperfede the neceffity of employing a fecond perfon at the loom. In this loom the tail of the harnefs, inftead of having its direction changed, by paffing over pullies, and being carried to one fide, rifes perpendicularly, and is made faft to the roof. The fimples are brought in a horizontal direction to the front of the loom, over the weaver's head. The direction of the fimples is very fimilar to that of the tail cords of the diaper-loom, *fig.* 1. The lafhes hang down perpendicularly, fo that the weaver may pull them with his hand. Upon the tail are knots, placed at equal heights from the floor, and in front of thefe knots is an inftrument very much refembling a coarfe comb, or the teeth of a garden rake. This inftrument moves upon a fulcrum, from which a lever extends over the weaver's head, by depreffing the end of which he can raife the teeth at pleafure. The fimples being pulled, the tail is drawn forward, and the knots engaged between the teeth of the comb. The lever being then pulled down, and fecured by a cord and handle, as in the diaper-loom; the teeth rife, and carrying the knots along with them, raife the harnefs. When a change is required, the teeth are let down, the knots relieved, a fecond fet pulled in, and the operation proceeds as before.

This plan has come into very general ufe, and feems to meet with much approbation, for thofe kinds of damafk where the pattern is not very extenfive. In the others, there is ftill a diverfity of opinion refpecting the comparative merits of the old and new plans, which, as the invention is recent, will probably be only decided by experience.

The draw-loom is alfo applied, in moft inftances, to the manufacture of carpets. Carpets are not tweeled like diaper or damafk, but confift of plain or alternate weaving. A carpet confifts of two webs of cloth, woven feparately and independently of each other, but being woven at the fame time, particular parts of them are taken through each other, fo that any part of each web is fometimes above, and fometimes below the other. From this it arifes that when a carpet is turned upfide down, the pattern remains the fame, but the colours are reverfed, that which formed the ground being now the pattern, and *vice verfa*.

The front mounting of a carpet draw-loom confifts of four leaves, two of which raife the web which forms the ground, and the other two that which forms the figure. One fhot of the woof is inferted into each web alternately. The eyes of the front mounting are long, like thofe of the diaper and damafk, to allow the harnefs to rife freely. As carpets are woven generally of coarfe dyed woollen yarn, and do not contain much warp, it is unneceffary, except in very complicated patterns, to ufe fimples. The lafhes, therefore, hang perpendicularly from the tail, and at the end of each fet there is a fmall handle, or as it is called, a *bob*. Thefe pafs through a long horizontal board, perforated with holes to preferve their regularity, and are arranged in pairs, one bob raifing the harnefs of the pattern-web, and the other that of the ground-web. To adapt the figure upon the defign to the application of the lafhes, the inftructions for the pattern-web are the fame as in the damafk; thofe for the ground-web the fame exactly reverfed. In the latter, therefore, the blanks upon the defign are to be taken, and the coloured fquares paffed. In this confifts the whole difference.

The harnefs of the fpot draw-loom is exactly the fame as

the damaſk, excepting that the yarn of the warp being much finer, the mails are not uſed, but ſhort eyes of twine ſubſtituted in their places. In the front mounting, alſo, the end is attained by means which, although in effect the ſame, are better adapted to the particular nature of the work. Four leaves of heddles are uſed; but they are mounted, ſo that two leaves will either go together up or down, or in oppoſite directions. The heddles are conſtructed like thoſe for weaving plain cloth, and every thread is drawn through two heddles, being taken through the upper cleft or link of the one, and through the under link of the other. When the two leaves move in the ſame direction, the threads of warp are confined as in the claſp of a common heddle; but when they move in a contrary direction, they preſent all the facility of the long eye in allowing the harneſs to riſe without interruption.

As the time, labour, and materials, neceſſary to mount a draw-loom involve a very conſiderable expence, before any productive return can be attained, it is of the utmoſt importance that the quality of the materials ſhould be good, and that every part ſhould be ſquare, level, and equally ſtretched. Draw-looms will only gradually remunerate thoſe who expend money or labour in fitting them up; and the better they are executed, the quicker and more certain will be the return. A trifling additional trouble or expence to attain thoſe ends will therefore always be found conſiſtent with the ſoundeſt judgment, and trueſt economy.

Draw-*Net*, a kind of net for taking the larger ſort of wild fowl, which ought to be made of the beſt packthread, with wide meſhes: they ſhould be about two fathoms deep, and ſix long, verged on each ſide with a very ſtrong cord, and ſtretched at each end on long poles.

It ſhould be ſpread ſmooth and flat upon the ground, and ſtrewed over with ſedge, graſs, or the like, to hide it from the fowl; and the ſportſman is to place himſelf in ſome ſhelter of graſs, fern, or ſome ſuch thing.

Dredging-machine

DREDGING-Machine, in *Mechanics*, an engine used to take up mud, or gravel, from the bottom of rivers, canals, docks, harbours, &c. while they remain full of water.

The common method of dredging is performed by men in a barge: the gravel, or ballast, is taken up in a leather bag, the mouth of which is extended by an iron hoop, attached to a light pole, of a sufficient length to reach the bottom: in the small way, two men are employed to work each pole. The barge being moored, one of the men takes his station at the stern, with the pole and bag in his hand, the other stands in the head, having hold of a rope, tied fast to the hoop of the leather bag. The man at the stern now puts the pole and bag down, over the barge's side, to the bottom, in an inclined position. The hoop being farthest from the man in the head of the barge, and having a rope, one end of which is fast to the gunwale of the barge, he passes it twice, or thrice, round the pole, and then holds it tight: the man in the head now pulls the rope, fastened to the hoop, and draws the hoop and bag along the ground, the other allowing the pole to slip through the rope as it approaches the vertical position, at the same time causing such a friction, that the hoop digs into the ground, the leather bag receiving whatever passes through the hoop: both men now assist in getting a bag into the barge, and delivering its contents.

When the bag is large, several men are employed; and, to increase the effect, a windlass, with wheel-work, is used to draw the hoop along the ground. It is in this manner the convicts at Woolwich upon the Thames perform the ballast heaving, or dredging, which they are condemned to labour at as a punishment.

In large rivers, which require much dredging to keep the channel at the proper depth, the above method of manual labour becomes so expensive, that a large machine, worked by horses or a steam engine, is usually employed; two such machines worked by a steam engine have been some time in use in the river Thames, one of them is represented in *Plate* III. *Hydraulics*, which contains an elevation and plan of the engine.

It is erected in the hulk of a dismasted ship. A A, *fig.* 1, is a frame of timber bolted to the starboard gunwale, to support a large horizontal beam, B B, *fig.* 2; another similar frame is fixed up in the middle of the ship at D, *fig.* 2, and the end of the beam is sustained by an upright post bolted to the opposite gunwale; the starboard end of the beam projects over the vessel's side, and has an iron bracket S fastened to it, to support one of the bearings for the long frame E E, composed of four timbers bolted together: the other end of the frame is suspended by pulleys *a*, *a*; from a beam F fixed across the stern, the upper ends of the outside beams of the frame E E have each a stout iron bolted to them, which are perforated with two large holes to receive two short cast iron tubes, one fastened to the iron bracket S at the end of the beam B, and the other to a cross beam of the frame A; these tubes act as the pivots of the frame E, upon which it can be raised or lowered by the pulleys *a*,*a*: they also contain bearings for an iron axis, on which a wheel or trundle O is fixed, containing four rounds. Another similar trundle P is placed at the bottom of the frame E E, and two endless chains *k*, *k*, pass round both, as is seen in the plan. Between every other link of the two chains, a bucket of plate iron *b b b* is fastened, and as the chain runs round, the buckets bring up the soil; a number of cast iron rollers *d*, *d*, are placed between the beams of the frame to support the chain and buckets as they roll up. Four rollers *e*,*e*, are also placed on each of the outside beams, to keep the chains in their places on the frame, that they may not get off to one side. The motion is conveyed to the chains by means of a cast iron wheel at G in the plan, wedged on the end of the axis of the upper trundle O. The wheel is cast hollow, like a very short cylinder, and has several screws tapped through its rim, pointing to the centre, and pressing upon the circumference of another wheel inclosed within the hollow of the first, that it may slip round in the other where any power greater than the friction of the screw, is applied; the internal wheel is wedged on the same shaft with a large cog-wheel *f* turned by the small cog-wheel *g* on the axis of the steam-engine. The steam-engine is one of that kind called high pressure, working by the expansive force of the steam only, without condensation; *h* is the boiler containing the fire place and cylinder within it; *i* is one of the connecting rods, and *l* the fly wheel on the other end of the same shaft as the wheel *g*. For a more particular description of the engine, see Steam Engine.

The pulleys *a*, which suspend the chain frame, are reeved with an iron chain, the tackle fall of which passes down through the ship's deck, and is coiled on a roller *m* in the plan, and represented by a circle in the elevation: on the end of the roller is a cog-wheel *p*, turned by the engine wheel *g*: the bearing of this wheel is fixed upon a lever, one end of which comes near that part of the steam-engine, where the cock which regulates the velocity of the engine, is placed; so that one man can command both lever and cock, and by depressing that end of the lever, cause the wheel *p* to geer with *g*, and consequently be turned thereby, and wind up the chain of the pulleys; *g* is a strong curved iron bar bolted to the vessel's side and gunwale, passing through an eye bolted to the frame E, to keep the frame to the vessel's side, that the tide or other accident may not carry it away.

A large hopper or trough is suspended beneath the wheel *o*, by ropes from the beam B, into which the buckets *b*, *b*, *b*, empty the ballast they bring from the bottom; the hopper conveys it into a barge brought beneath it: this hopper is not shewn in the plate, as it would tend to confuse parts already not very distinct. The motion of the whole machine is regulated by one man. The vessel being moored fast, the engine is started, and turns the chain of buckets, the engine tender now puts his foot upon a lever, disengages the wheel *p* from *g*, and by another takes off a gripe which embraced the roller *m*. This allows the end E of the frame to descend, until the buckets on the lower half of the chain drag on the ground, as shewn in *fig.* 1, when he stops the further descent by the gripe, the buckets are filled in succession at the lower end of the frame, and brought up to the top, where they deliver their contents into the hopper before-mentioned: as they take away the ballast from the bottom, the engine tender lets the frame E down lower by means of the gripe lever, and keeps it at such a height that the buckets come up nearly full; if at any time the buckets get such deep hold as to endanger the breaking of the chain or stopping the engine, the coupling-box at G before-described, suffers the steam-engine to turn without moving the chain of buckets, and the engine tender pressing his foot upon the lever which brings the wheel *p* to geer with *g*, causes the roller *n* to be turned by the engine, and raise up the frame E, until the buckets take into the ground the proper depth, that the friction of the coupling-box at G will turn the chain without slipping in any considerable degree.

The steam engine is of six horses power, and is so expeditious, that it loads a small barge with ballast in an hour and a half.

Drill

Drill, in *Mechanics*, a tool made of hardened ſteel, uſed to bore holes in metal; they are of various forms, the moſt uſeful of which are ſhewn in *Plate* XXIV. *Mechanics*.

Fig. 1. is the common lathe or crank-drill, having an angular point, and two cutting edges, *a a*, which are only adapted to be turned one way; it is therefore adapted for drilling any work in the lathe, or by the crank, which is formed of iron, having a ſocket at the lower end to receive the drill; the upper end is pointed, and is preſſed upon by a lever loaded with a weight. The workman turns the drill round by means of the elbow of the crank, and the weight and lever keep it to its work.

Fig. 2. is the ordinary drill, having the cutting edge, as ſhewn in the ſide view B, made ſo as to cut either way; it is uſed with the crank, but chiefly with the bow.

Fig. 3. is like the former, except that it has a round edge; it is uſed for drilling ſteel and hardened iron, where, from the hardneſs of the work, a point might fail.

Fig. 4. is a drill, where the cutting edge (*a b* in *fig*. D.) croſſes the point. The cutting ſide of the edge at *a* is toward *fig*. A: and at the other ſide of the centre; *viz*. at *b*, it is toward D; the edge is therefore ſomewhat like a ſcrew, and leads itſelf into the work; for which reaſon it is good for drilling lead, copper, and other metals, which are tough without being very hard.

Fig. 5. is called a pin drill, and is uſed for drilling very large holes. A ſmall drill, like *figs*. 1 or 2, is firſt uſed, and the hole, thus made, juſt fits the pin *a a*, and keeps the drill ſteady while it is turned round. It has two cutting edges, *b* and *d*; in *b* the face is towards the eye of the ſpectator, and *d* repreſents the back of the edge; the edge is a little hollowed out above at *b* in the edge view, to make a thinner and ſharper edge.

Fig. 6. is a counterſunk drill, which is uſed to make holes to receive the heads of ſcrews; a hole is firſt drilled by the common drill, which is the ſize of the body of the ſcrew, and the pin *a a* juſt fits it, the cutting part *d b* is the ſize of the head of the ſcrew, *e e* is a ſhoulder, which prevents the drill cutting any further than intended.

Drills for ſmall work are turned by means of a ſmall pulley fitted on them; the ſtring of an elaſtic bow is paſſed round it. The piece of metal to be drilled, is fixed in a vice, and the point of the drill applied to it; the other end is placed in a hole in a piece of metal held againſt the breaſt of the operator; by drawing the bow backwards and forwards, a rapid motion is given to the drill, though it is not always in the ſame direction; therefore, the drill ſhould be ſhaped like *fig*. 1.

To avoid the trouble of making a great number of pulleys, workmen frequently uſe drill ſtocks, which will fit any ſize drill with the ſame pulley.

Fig. 7. is one of theſe where the drill A is formed of a round piece of ſteel wire, and puſhed into a round hole, a little taper in the end of the ſtock B; *a*, *a*, are notches to puſh out the end of the drill in caſe it breaks in the ſtock. Sometimes the hole in the ſtock is ſquare, for unleſs the work is very light, the round ones are apt to ſlip.

Fig. 8. is a neat contrivance to obviate this difficulty, communicated to us by Mr. T. Gill. The hole in the end of the ſtock is cylindrical, and the wire of the drill has one ſide filed flat, a ſmall pin is put through one ſide of the hole, as ſhewn by the ſmall round circle, and the flat ſide of the wire applies itſelf to it; by this means, the drill cannot turn round, and always fits tight in its ſocket.

Fig. 9. is a ſteel bow for giving motion to a drill as before explained. A is the ſteel part formed into a hook at the end, to hold the catgut B. At the other end, the ſteel is enlarged to receive a thumb-nut D, on which the catgut is wound, *d* is a ſmall ratchet wheel faſtened to the nut D, and fitted with a click to prevent its turning back. The uſe of the ratchet is to draw up the catgut, ſo that it may fit any ſize pulley on the drill.

In large manufactories where much large drilling is to be performed, it is done by machinery uſually turned by a ſteam engine.

Figs. 10. and 11. are elevations, at right angles to each other, of a machine of this kind. A, *fig*. 10, is a ſhaft, bringing the power to the machine, B a bevelled wheel fixed thereon, giving a rotative motion to another, D, on a vertical axis, E, turning in bearings *d*, *d*; this axis is perforated with a ſquare hole throughout to receive a ſquare iron bar *e*, at the lower end whereof the drill *f* is fixed. The work to be drilled is placed on a ſtool F upon the floor, that it may be readily moved about; in the drawing it is ſuppoſed to be a cylinder lid; the drill is preſſed down upon the work by a lever G, the fulcrum of which is *g*, at the other end of the lever is jointed an iron rod *h*, having a rack *k* cut in the lower end; this rack is moved by a pinion on the axis of a toothed wheel *l* turned by another pinion, on whoſe ſpindle is the winch *m*; the upper end of the iron bar *e* is pointed, and works in a hole in the lever; a collar *n* is put over the lever and keyed upon the bar *e*, ſo that the lever will lift up the drill as well as force it down upon the work.

The operation of the machine is very ſimple; the drill being conſtantly in motion, the workman turns the winch *m*, and raiſes the drill above the work, he then adjuſts the work by moving the ſtool F and laying the piece upon wedges to the proper place, and by turning the winch *m* back, he brings the drill down upon the work with any degree of force he pleaſes. The drill muſt be ſupplied with cold water, otherwiſe the friction would heat and ſoften it. The drill is fitted into its ſocket by a ſquare, the ſocket is open above the drill, as ſhewn in *fig.* 11, that it may be driven out to change it for another.

Drills are hardened by heating them in the fire to a red heat, and plunging them in cold water. They are then rubbed bright in ſome part by a ſtone, file, &c. and again heated in the fire, till the bright part aſſumes a light ſtraw colour, when they are cooled in water. Small drills are heated in the candle by a blow pipe, and cooled in the tallow.

It is a very well known fact, that a drill made of iron has frequently not only a polarity, but ſo ſtrong an attractive virtue of the magnetic kind, that it will ſuſpend a common needle from its point. It is uſually ſuppoſed that a drill acquires this polarity by boring iron. But it is not only by boring of iron that, this power is obtained, but in the very making. As ſoon as one of them is finiſhed and hardened, its point becomes a north pole before it has ever been worked either in iron or any other materials, ſo that of the great numbers of theſe inſtruments found in a ſhop, endowed with this power, it is to be ſuppoſed that more of them owe it to their original make than to any after-uſe. All pieces of wrought iron, which in ſhape reſemble drills, that is, which are of a long and ſlender form, will not only have this polarity, but they will change it on being placed for ſome time in an inverted poſture, and that which was the oppoſite to the north pole, by ſtanding downwards will be the north pole. This has been an old obſervation, but on a fair experiment it does not prove to be true in all things without exception, though it be ſo in moſt particulars. The larger pieces of iron ſeem to be moſt eaſily influenced in their polarity, by changing their poſition; but the ſmall ones will ſometimes be found to have fixed poles, which no change of poſture will alter. Phil. Tranſ. N° 246. See MAGNET.

Ductility

DUCTILITY, (from the Latin *ductile*,) means the property, or the capability, of becoming extended. The word *expansibility* has been more commonly applied to denote the enlargement of such bodies as consist, or seem to consist, of separate parts, like the effluvia of odoriferous substances, colouring pigments, cotton, wool, &c. But the word *ductility*, denotes the enlargement of the dimensions of solids, without losing their continuity and consistence. This property almost exclusively belongs to metallic bodies; for it can hardly be discerned in a few other bodies.

The methods of extending metallic bodies may be reduced to three: *viz*. by the strokes of a hammer, by the more equable pressure of flatting or rolling mills, and by drawing the metal through small holes in a steel plate, as is practised in wire-drawing. And since the first of those methods has been more generally and more usually practised; therefore the words malleability and ductility have been indiscriminately used to express the same thing.

To these impressions certain metallic bodies yield much more readily than others, and some there are which will not yield at all; so that, when pressed or hammered, they will rather break into fragments than expand.

Previous to the statement of the various degrees of ductility, it will be necessary to say a few words with respect to the nature of dilatability itself, in order to prevent a wrong notion which unexperienced persons are liable to adopt. When a piece of metal, in consequence of its ductility, is said to be extended; the meaning is not that the bulk of the metal is enlarged; but that one or two of its dimensions, (*viz*. the length, the breadth, or the thickness,) is enlarged, whilst one or both the others are diminished. For instance, a cubic inch of gold is one inch long, one inch broad, and one inch thick; and the product of these three dimensions, which gives the solidity, is one inch. Now if, by hammering, you extend the length of it, so as to make it two inches long, the breadth remaining the same, the thickness will be reduced to half an inch; and the product of these three dimensions; *viz*. two inches, one inch, and half an inch, is equal to one inch, as before; which shews that the solid contents remain the same.

It must, however, be observed, that, strictly speaking, the bulk of a piece of metal is a little contracted by the hammering or pressing; so that a sort of concentration and hardening take place at the same time. In fact, the specific gravity of a piece of ductile metal is greater after the hammering or pressing than before. Both this additional hardness and increased specific gravity are removed by heating the piece of metal to a certain degree.

Though we have mentioned the drawing through holes as one of the methods of extending metallic bodies; yet a necessary distinction must be pointed out with respect to this operation.—In the present state of philosophy, *ductility* is distinguished from *tenacity*. The meaning of the former has already been explained; but the tenacity is measured by the resistance which a wire of the metal opposes, without breaking, to the action of a certain force which draws it at one extremity, while the other extremity is fixed. Now it is upon this tenacity that the drawing of metals through holes depends. And, in fact, certain metals which shew under the hammer, or under the flatting mill, a much greater degree of ductility than others, are, at the same time, less capable of being drawn into fine wire, and *vice versâ*; as will appear from the following lists.

Of all the metallic bodies some are ductile, whilst others are not, and this difference caused them to be distinguished into two classes; calling the former metals, and the latter semi-metals, or imperfect metals; but the limits of these classes being very indefinite, little regard is now paid to this nominal distinction.

Ductile Metallic Bodies arranged in the Order of their Ductility.

Gold,	Iron,
Platina,	Tin,
Silver,	Lead.
Copper,	

Metallic Bodies arranged in the Order of their Tenacity.

Gold,	Silver,
Iron,	Tin,
Copper,	Lead.
Platina,	

For farther particulars reſpecting the tenacity of metals, ſee the articles TENACITY, and WIRE *Drawing*.

The ductility of gold exceeds that of every other metallic body, and ſince its value and its beauty have at all times encouraged the induſtry of workmen, no pains have been ſpared in endeavouring to expand the ſurface of it to the utmoſt limit of practicability; and a ſingle grain weight of gold is now commonly extended into a ſurface equal to 50 ſquare inches and upwards. Mr. Magellan ſays, that the fineſt gold leaf is extended by hammering between new ſkins, and that each troy ounce of pure gold muſt be alloyed with three grains of copper, otherwiſe it would be too ſoft to paſs over the irregularities of the ſkins. When extended to the utmoſt, 2000 leaves of ſuch gold, each containing a ſurface of 10.89 ſquare inches, weigh leſs than 384 grains; ſo that each grain weight of the metal will produce about 57 ſquare inches of gold leaf; and it is eaſily determined by calculation, that the thickneſs of ſuch gold leaf is about $\frac{1}{282000}$th of an inch. However, this is a conſiderable thickneſs, in compariſon of that of gold ſpun on ſilk in our gold thread.

To conceive this prodigious ductility, it is neceſſary to have ſome idea of the manner, wherein the wire-drawers proceed. The wire and thread we commonly call gold thread, &c. which is only ſilver wire gilt, or covered over with gold, is drawn from a large ingot of ſilver, uſually about thirty pounds weight. This they round into a cylinder, or roll, about an inch and a half in diameter, and twenty-two inches long, and cover it with the leaves prepared by the gold-beater, laying one over another, till the cover is a good deal thicker than that in our ordinary gilding; and yet, even then, it is very thin; as will be eaſily conceived from the quantity of gold that goes to gild the thirty pounds of ſilver: two ounces ordinarily do the buſineſs: and, frequently, little more than one. In effect, the full thickneſs of the gold on the ingot rarely exceeds $\frac{1}{300}$th, or $\frac{1}{500}$th part: and ſometimes not $\frac{1}{1000}$th part of an inch.

But this thin coat of gold muſt be yet vaſtly thinner: the ingot is ſucceſſively drawn through the holes of ſeveral irons, each ſmaller than the other, till it be as fine, or finer, than a hair. Every new hole leſſens its diameter; but it gains in length what it loſes in thickneſs; and, of conſequence, increaſes in ſurface: yet the gold ſtill covers it; it follows the ſilver in all its extenſion, and never leaves the minuteſt part bare, not even to the microſcope. Yet, how inconceivably muſt it be attenuated while the ingot is drawn into a thread, whoſe diameter is 9000 times leſs than that of the ingot!

M. Reaumur, by exact weighing, and rigorous calculation found, that one ounce of the thread was 3232 feet long; and the whole ingot 116,3520 feet, Paris meaſure, or 96 French leagues; equal to 126,4400 Engliſh feet, or 240 miles Engliſh; an extent which far ſurpaſſes what Fa. Merſenne, Furetiere, Dr. Halley, &c. ever dreamt of.

Merſenne ſays, that half an ounce of the thread is 100 toiſes, or fathoms long; on which footing, an ounce would only be 1200 feet; whereas, M. Reaumur finds it 3232. Dr. Halley makes ſix feet of the wire one grain in weight, and one grain of the gold ninety-eight yards; and, conſequently, the ten thouſandth part of a grain, above one third of an inch. The diameter of the wire he found one 186th part of an inch; and the thickneſs of the gold one 154,500th part of an inch. But this, too, comes ſhort of M. Reaumur; for, on this principle, the ounce of wire would only be 2680 feet.

But the ingot is not yet extended to its full length. The greateſt part of our gold thread is ſpun, or wound on ſilk, and, before they ſpin it, they flat it by paſſing it between two rolls, or wheels of exceedingly well poliſhed ſteel; which wheels, in flatting it, lengthen it by above one ſeventh. So that our 240 miles are now got to 274. The breadth, now, of theſe laminæ, or plates, M. Reaumur finds, is only one 8th of a line, or one 96th of an inch; and their thickneſs, one 3072d. The ounce of gold, then, is here extended to a ſurface of 1190 ſquare feet; whereas, the utmoſt the gold beaters can do, we have obſerved, is to extend it to 146 ſquare feet. But the gold, thus exceedingly extended, how thin muſt it be! From M. Reaumur's calculus, it is found to be one 175,000th of a line, or one 2,100,000th of an inch: which is ſcarce one 13th of the thickneſs of Dr. Halley's gold. But he adds, that this ſuppoſes the thickneſs of the gold every where equal, which is no-ways probable; for in beating the gold-leaves, whatever care they can beſtow, it is impoſſible to extend them equally. This we eaſily find, by the greater opacity of ſome parts than others; for where the leaf is thickeſt, it will gild the wire the thickeſt.

M. Reaumur, computing what the thickneſs of the gold muſt be where thinneſt, finds it only the 3,150,000th part of an inch. But what is the one 3,150,000th part of an inch? Yet this is not the utmoſt ductility of gold: for inſtead of two ounces of gold to the ingot, which we have here computed upon, a ſingle one might have been uſed; and, then, the thickneſs of the gold, in the thinneſt places, would only be the 6 300,000th part of an inch.

And yet, as thin as the plates are, they might be made twice as thin, yet ſtill be gilt; by only preſſing them more between the flatter's wheels, they are extended to double the breadth, and proportionably in length. So that their thickneſs, at laſt, will be reduced to one thirteenth, or fourteenth millionth part of an inch.

Yet, with this amazing thinneſs of the gold, it is ſtill a perfect cover for the ſilver: the beſt eye, or even the beſt microſcope, cannot diſcover the leaſt chaſm, or diſcontinuity. There is not an aperture to admit alcohol of wine, the ſubtileſt fluid in nature, or even light itſelf, unleſs it be owing to cracks occaſioned by repeated ſtrokes of the hammer. Add, that if a piece of this gold-thread, or gold-plate, be laid to diſſolve in aquafortis, the ſilver will be all excavated, or eat out, and the gold left entire, in little tubules.

It ſhould be obſerved, that gold, when it has been ſtruck for ſome time by a hammer, or violently compreſſed, as by gold wire-drawers, becomes more hard, elaſtic, and ſtiff, and leſs ductile, ſo that it is apt to be cracked or torn: the ſame thing alſo happens to the other metals by percuſſion and compreſſion. But ductility and tractability may be reſtored to metals in that ſtate, by annealing them, or making them red-hot. Gold ſeems to be more affected by percuſſion and annealing, than other metals.

Platina, ſilver, and copper, may, likewiſe, be expanded into leaves, but not nearly ſo thin as thoſe of gold.

With reſpect to the arrangement of iron and tin in the firſt of the above-ſtated liſts, we are not quite determined as to which of them the preference may be due.

Zinc has the remarkable property of being malleable, or ductile, not in the uſual temperature of the atmoſphere, but in a higher temperature. When heated to between 210° and 300° of Fahrenheit's thermometer, zinc is perfectly malleable, and may be ſtretched into wires, or into pretty thin plates. And when ſo treated, it will afterwards remain mal-

leable. Some metallic fubftances do not fuffer the ftrokes of a hammer nearly fo well as the more uniform preffure of the flatting mill; and this is peculiarly the cafe with zinc.

It is not with zinc alone, but with all other ductile metals, that their ductility is greater in a certain temperature, which generally exceeds that of the atmofphere; thus iron in a red heat is incomparably more ductile than at a lower temperature. Heat, in fhort, tends to foften the metal; or, which amounts to the fame thing, to increafe its ductility; and as hammering or rolling hardens the metal at the fame time that it extends it, the workmen, in the courfe of their operation, find it neceffary to foften the metal by the application of heat, in order to render it capable of farther extenfion. This heating or foftening is, in fome cafes, repeated feveral times before the work is quite finifhed.

The alloys of two or more metallic bodies are lefs ductile, than the pure metals themfelves; yet fuch alloys are highly ufeful in a variety of cafes, and the pure metals are often alloyed for no other purpofe than for diminifhing their foftnefs and ductility. In the coinage of moft countries the noble metals are generally alloyed with a little copper, which increafes their hardnefs and elafticity.

The moft extenfively ufeful alloy is that of copper and zinc, which forms *brafs*.—Its colour, its ductility, and its not being eafily oxydated, have rendered it peculiarly ufeful for a variety of purpofes, and efpecially in watch-work, where no other metallic fubftance has been found nearly fo ufeful.

Brafs, when properly made, is ductile and tenacious to a confiderable degree. It will extend pretty well under the hammer, and it may be eafily drawn into very fine wire. A flight degree of heat will, in fome meafure, increafe its ductility; but when heated to about 300°, or upwards, then the ftrokes of the hammer will reduce it to powder. It is a fort of brafs (but the precife proportion of the ingredients is kept fecret,) that is expanded into leaves like gold; and is commonly fold under the name of *Dutch gold*.

Though tin is more ductile than zinc; yet the alloy of copper and tin is, upon the whole, lefs ductile than that of copper and zinc. Paerner fays, that much copper and little tin form a malleable compound, as well as much tin and little copper; but that when the two metals are alloyed from eight to ten parts of copper to one of tin, then the alloys are brittle and untractable.

The alloy of lead and antimony forms the metal which is ufed for printer's types, and its ductility may be varied by varying the proportion of antimony. According to Gmelin, one part of antimony and 12 parts of lead, form a hard alloy, but capable of being beat into fheets. One part of antimony and eight parts of lead, form a compound harder and more fufible than lead, but malleable; and fuch is alfo the cafe with one part of antimony and three of lead; but with a fmaller proportion of lead the compound is too hard to bear the ftrokes of the hammer.

An alloy of zinc and lead has, on account of its brilliancy and hardnefs, been recommended for the conftruction of economical and other articles. When a great deal of zinc is alloyed with lead, the compound is harder than lead, but very malleable. See METALS, GOLD, &c.

DUCTILITY *of Glafs*. We all know, that, when well penetrated with the heat of the fire, the workman can figure and manage glafs like foft wax; but what is moft remarkable, it might be drawn, or fpun out into threads, exceedingly fine and long.

Our ordinary fpinners do not form their threads of filk, flax, or the like, with half the eafe and expedition, as the glafs fpinners do threads of this brittle matter. We have fome of them ufed in plumes for children's heads, and divers other works, much finer than any hair, and which bend and wave like it with every wind.

Nothing is more fimple and eafy than the method of making them: there are two workmen employed; the firft holds one end of a piece of glafs over the flame of a lamp; and, when the heat has foftened it, a fecond operator applies a glafs hook to the metal thus in fufion; and, withdrawing the hook again, it brings with it a thread of glafs, which ftill adheres to the mafs: then, fitting his hook on the circumference of a wheel about two feet and a half in diameter, he turns the wheel as faft as he pleafes; which, drawing out the thread, winds it on its rim; till, after a certain number of revolutions, it is covered with a fkain of glafs thread.

The mafs in fufion over the lamp diminifhes infenfibly; being wound, as it were, like a pelatoon, or clue of filk, upon the wheel; and the parts, as they recede from the flame, cooling, become more coherent to thofe next to them; and this by degrees: the parts neareft the fire are always the beft coherent, and, of confequence, muft give way to the effort the reft make to draw them towards the wheel.

The circumference of thefe threads is ufually a flat oval, being three or four times as broad as thick: fome of them feem fcarce bigger than the thread of a filk-worm, and are furprifingly flexible. If the two ends of fuch thread be knotted together, they may be drawn and bent, till the aperture, or fpace in the middle of the knot, doth not exceed one 4th of a line, or one 48th of an inch diameter.

Hence M. Reaumur advances, that the flexibility of glafs increafes in proportion to the finenefs of the threads; and that, probably, had we but the art of drawing threads as fine as a fpider's web, we might weave ftuffs and cloths hereof for wear. Accordingly, he made fome experiments this way; and found he could make threads fine enough, as fine in his judgment, as any fpider's web: but he could never make them long enough to do any thing with them.

Durham

DURHAM, a county in the northern part of England, bounded to the eaſt by the German ocean, to the north by Northumberland, from which it is ſeparated by the rivers Tyne and Derwent, on the weſt by the counties of Cumberland and Weſtmoreland, and on the ſouth by Yorkſhire. The area thus encloſed forms a triangular figure, and meaſures about 36 miles in its greateſt extent from north to ſouth, by nearly 45 miles in an oppoſite direction. Its ſu-

This part of England was anciently inhabited by the *Brigantes*, a claſs of Britons, diſtinguiſhed by Tacitus as being powerful, brave, and numerous; but who were ſubdued by the Romans. The latter included Durham within the diviſion of Maxima Cæſarienſis; and the Saxons made it part of the kingdom of Northumbria. In the year 685, Egfrid, king of this diſtrict, granted all the lands between "the rivers Weare and Tyne" to St. Cuthbert, the apoſtle of the north. From this time the county was inveſted with great privileges, and has been generally termed the *Biſhopric*, and *County palatine*. Edward I., however, ſeized the power from the biſhop, and transferred the liberties of the ſee to the crown. Theſe were afterwards reſtored in part; and were augmented or enlarged by different monarchs, till queen Mary re-eſtabliſhed them. The biſhops of Durham, from time immemorial, have exerciſed peculiar immunities and power; conſiſting of all manner of royal juriſdiction, both civil and military, by land and ſea. For the exerciſe of which they had their proper courts of chancery, exchequer, and court of pleas, as well of the crown as of the county. The nature and peculiarity of all theſe cannot be properly deſcribed in this place, but may be found fully explained in Hutchinſon's Hiſtory of Durham, 3 vols. 4to. and Gough's edition of Camden's Britannia, vol. iii. p. 109, &c.

The general aſpect of Durham is hilly and mountainous, particularly towards the weſtern angle, which is a bleak, barren, and naked region, croſſed by a lofty ridge called the Engliſh Apennines. Several different ſtreams iſſue from the eaſtern ſide of theſe mountains. On the eaſtern ſide, and near the centre of the county, are ſome fine and fertile vallies, through which various brooks and rivers flow to the ſea. Nearly one-third of the land is held by eccleſiaſtical tenure, under leaſes for lives, or for 21 years. The cattle of Durham are in great repute, as to ſhape, weight, produce of milk, &c. The ſheep are moſtly large, and covered with long wool.

The waſte or uncultivated lands of this county are of conſiderable extent, occupying, according to Mr. Granger,

perficial area includes about 610,000 acres. This ſpace is divided into four wards, all of which derive their names from places of little importance, *viz.* Cheſter, Darlington, Eaſington, and Stockton; beſides which there are two other diſtricts, called Norhamſhire and Iſlandſhire. The county is divided, according to ſome authors, into 113 pariſhes, while others ſay 120, including one city and ten market towns. According to the laſt report to parliament, this diſtrict contained 27,195 houſes, and 160,361 inhabitants, of whom 74,770 were males, and 85,591 were females. Four members are returned to parliament; two for the county and two for the city.

nearly 130,000 acres. According to ſir William Appleby, in a communication to the author of the Agricultural Report, "Durham, taking its ſmall dimenſions into conſideration, is not to be equalled by any other county in Great Britain, except Middleſex, for its numerous and important coal, lead, and iron mines; its large caſt-metal founderies, and iron manufactories, potteries, glaſs-houſes, copperas works, coal, tar, and ſalt works, quarries of marble, fire and free-ſtone; lime, brick, and tile-kilns; grind-ſtone and mill-ſtone; linen and woollen manufactories; trade, agriculture, and population." Granger's general View of the Agriculture of the County of Durham, 4to.

Towards the eaſt and north-eaſt parts of Durham are ſeveral extenſive coal-mines. The ſeams or ſtrata, now worked, are five in number, which extend horizontally for many miles, and are from 20 to 100 fathoms beneath the ſurface. Each ſtratum is from three to about eight feet in thickneſs. Below theſe are ſeveral other ſeams of coal. Some ſteam-engines have been erected, to raiſe the coal to the ſurface, and for the purpoſe of pumping the water out of the mines. In the great ſea-ſale collieries, ſeveral horſes are conſtantly kept under ground, to draw the coals to the mouths of the pits.

In the vicinity of Walſingham, a firm black ſpotted limeſtone or marble is procured, and is much uſed for hearths, chimney-pieces, &c. The ſame neighbourhood alſo abounds with ſtone, much uſed in making mill-ſtones. Many quarries of excellent ſlate have been opened in different parts of the county; and Gateſhead-fell is particularly famous for producing what are vulgarly termed Newcaſtle grind-ſtones, from being moſtly ſhipped off at that port. Fire-ſtone, in high eſtimation for making ovens, furnaces, &c. is obtained in various parts of the county; and large quantities are annually exported. Several lead-mines are worked in Teeſdale and Wear-dale. Some extenſive works for manufacturing ſalt from ſea-water have been long eſtabliſhed at South Shields; but theſe have been much neglected, in conſequence of a ſingular ſalt ſpring having been diſcovered at Birtley. The water riſes at the depth of 70 fathoms, and has produced 20,000 gallons *per* day for ſome years paſt. The water is found to be four times ſtronger than any ſea-water.

The manufactures of Durham are numerous and important, and are diſtributed over various parts of the county. At Cheſter-le-Street is a very extenſive foundery for cannon; and another at Waſhington. At Swalwell and at Winlaton are ſome very large iron-works; and at Lumley is a manufactory for converting ſcrap-iron into engine-boiler-plates, and caſt metal into malleable iron. At Shortley-Bridge, Derwent-Coal, and Blackhall-Mills, are manufactories of ſteel for ſword-blades. Tammies, carpets, and waiſtcoat-pieces, are manufactured at Durham; tammies and huckabacks are alſo made at Darlington; cottons are manufactured at Caſtle-Eden, Stockton, and Biſhops-Auckland; glaſs-bottles in large quantities are made at Sunderland, &c.

The chief rivers of this county are the Tees, the Weare, and the Derwent. The total return of income, under the influence of the property-tax bill for this county, in 1806, was 1,320,364*l.* The amount of the poor-rates for 1803, at 2*s.* 4½*d.* in the pound, was 71,665*l.*

Dyeing

DYEING, *History of.* The origin of the art of dyeing is involved in that obscurity which pervades the history of all those arts connected with the common wants and necessities of life. They have originated in times beyond the reach of history or tradition, and are the offspring of the natural faculties of man directed by the great primeval wants of food, shelter, and raiment. The art of dyeing is, of course, posterior to many of these, and is founded less on the necessities than passions of mankind. A love of distinction is common to man in every stage of civilization, but that passion for admiration which is displayed in a love of finery and ornament is peculiar to him in his most barbarous and uncultivated state. Hence savage nations delight in brilliant and gaudy colours, and many paint their skins, and adorn themselves with feathers, stones, and shells of various hues. History has not furnished us even with her fables on the origin of dyeing; but from analogy, as well as observation of the practice of barbarous nations at the present day, we may trace the rude beginnings from whence the art has sprung. The rich and gaudy plumage of birds, the finely spotted skins of animals, coloured stones, and such other substances as nature herself supplies, would afford the first materials for savage finery and dress. The caps and mantles of the chiefs of the South Sea islands, such as were brought home by captain Cook, are composed almost wholly of feathers richly coloured.

It is easy to conceive that accident must furnish innumerable instances of observation even to the eye of a savage, that many of these colours were capable of imitation, and that some substances readily imparted their colour to others. The bruising of a fruit, a flower, or leaf, is one of the most natural and obvious occurrences to which we should look for the first notion of applying vegetable juices to dyeing, and doubtless the knowledge of the tingent properties of various herbs was thus early acquired. The art, however,

muſt have waited the progreſs of induſtry and luxury, before it became extended and improved. Long antecedent, however, to the period when authentic hiſtory begins, it muſt have made conſiderable progreſs. Moſes ſpeaks of ſtuffs dyed blue, and purple, and ſcarlet, and of ſheep-ſkins dyed red. Theſe colours require great ſkill in the preparation, and the knowledge of them implies a very advanced ſtate of the art at that period.

The colour which appears to have been earlieſt brought to perfection, and which was held in ſuch high eſtimation among the ancients, is purple. It was to chance alone, according to the tradition of antiquity, that they owed this diſcovery. A ſhepherd's dog, inſtigated by hunger, having broken a ſhell on the ſea ſhore, his mouth became ſtained with ſuch a colour as excited the admiration of all who ſaw it. They endeavoured to apply it to ſtuffs, and ſucceeded. There is ſome diſcordance in the details of the ancient writers of the circumſtances of this event. Some place this diſcovery in the reign of Phœnix, ſecond king of Tyre, that is to ſay, a little more than 500 years before Chriſt: others, at the time that Minos the firſt reigned in Crete, about 1439 years before the Chriſtian era. But the greateſt number agree in giving the honour of the invention of dyeing purple ſtuffs to the Tyrian Hercules. He gave his firſt trials to the king of Phœnicia, who was ſo jealous of the beauty of this new colour, that he forbade the uſe of it to all his ſubjects, reſerving it for the garments of royalty alone.

Some authors relate the ſtory differently. Hercules's dog having ſtained his mouth with a ſhell, which he had broken on the ſea ſhore, Tyras, a nymph of whom Hercules was enamoured, was ſo charmed with the beauty of the colour, that ſhe declared to her lover ſhe would ſee him no more till he brought her a ſuit dyed the ſame. Hercules thought of a way to ſatisfy his miſtreſs; he collected a great number of the ſhells, and ſucceeded in ſtaining a robe of the colour the nymph had demanded. Such are the different traditions handed down by the ancients of the origin of the purple dye. They are evidently blended with fiction, yet they may ſerve to fix the epoch of this diſcovery, which appears to have been made about fifteen centuries before the Chriſtian era. Whether the purple of Tyre was ſimilar to that mentioned in holy writ, as uſed by Moſes for the veſtments of the high prieſt, and the ornaments of the tabernacle, may admit of ſome diſpute, ſince it is not certain, according to M. Huet, that the word *argaman*, of the Hebrew text, which all the interpreters tranſlate by *purpura*, means in reality that colour.

The teſtimony of Homer confirms the antiquity of this diſcovery. This great poet and accurate obſerver, aſcribes to the heroes of that age, in which we have ſuppoſed it became known, ornaments and cloths of purple.

The ancients had ſuch an eſteem for this colour, that it was eſpecially conſecrated to the ſervice of the deity. Moſes, as we have juſt obſerved, uſed ſtuffs of purple for the works of the tabernacle, and the habits of the high prieſt. The Babylonians gave purple habits to their idols; it was the ſame with moſt of the other people of antiquity. The Pagans were even perſuaded that the purple dye had a particular virtue, and was capable of appeaſing the wrath of the gods.

Purple was alſo the diſtinguiſhing mark of the greateſt dignities from the earlieſt times. We have ſeen that the king of Phœnicia, to whom tradition ſays the firſt eſſays of this colour were preſented, had it reſerved for the ſovereign. Among the preſents which the Iſraelites made to Gideon, the ſcripture makes mention of purple habits found among the ſpoils of the kings of Midian. Homer gives us plainly to underſtand, that it only belonged to princes to wear this colour; and we may remark, that this cuſtom was obſerved by all the nations of antiquity.

It is not eaſy to give a clear and preciſe idea of the proceſs followed by the ancients in the production of this highly valued colour. We find ſome details in the works of Ariſtotle and of Pliny, in whoſe days the practice was very common, but they are not ſufficiently circumſtantial. The purple dye, according to Pliny, was drawn from many ſpecies of ſhell fiſh. The beſt were found near the iſle where New Tyre was built. They fiſhed for them in other parts of the Mediterranean. The coaſts of Africa were famous for the purple of Getulia. The coaſts of Europe ſupplied the purple of Laconia, which was held in great eſteem.

In the 36th chapter of his ſeventh book, Pliny ranges in two claſſes the different kinds of ſhell fiſh which produced the purple. The firſt comprehended the ſmaller ſpecies under the denomination of *buccinum*, from their reſemblance to a hunting horn; the ſecond included thoſe denominated *purpura*. Theſe Fabius Columna conceives to have been alſo diſtinguiſhed by the generic name of *murex*, though others ſuppoſe this to have ſignified all the different ſpecies generally. All theſe ſeveral ſpecies, the chief of which are enumerated by Pliny, appear to have given colours of different ſhades, from which, by mixture of the liquors in various proportions, other varieties of colour were produced. A few drops only of this precious dye were obtained from each fiſh, by extracting a white vein placed in the throat; but to avoid this trouble with the ſmaller ſpecies, according to Ariſtotle and Pliny, the whole fiſh was bruiſed in a mortar, a practice which, according to Vitruvius, was often followed with the larger. The liquor, when extracted, was mixed with a conſiderable portion of ſalt, and ſuffered to remain three days; after which it was diluted with five or ſix times its quantity of water, and digeſted, moderately hot, during ten days, in a lead or tin veſſel, ſkimming it frequently, to ſeparate all impurities. The wool was afterwards put in, being well waſhed, cleanſed, and properly prepared. After ſoaking five hours, it was taken out, carded, and again immerſed in the boiling dye, till all the colour was taken up or exhauſted. To produce particular ſhades of colour, nitre, urine, and a marine plant called fucus, of which the beſt kind is found on the rocks of the iſle of Crete, were occaſionally added.

The Tyrians, by the confeſſion of all antiquity, ſucceeded beſt in dyeing ſtuffs purple. Their proceſs differed a little from what we have related above. They uſed nothing to make their colour but purple ſhells taken out at ſea. They made a bath of the liquor they drew from theſe fiſhes. They ſteeped their wool in this a certain time, and afterwards took it out and ſteeped it in another boiler, in which was nothing but buccina or trumpet fiſh. This is all the ancients tell us of the practice of the Tyrians. Wool, which had received this double Tyrian dye, (diabapha) was ſo very coſtly, that in the reign of Auguſtus, each pound ſold for 1000 Roman denarii, about 36*l*. ſterling. Nor need we wonder at this exceſſive price, when we conſider the tedious nature of the proceſs, and the ſmall quantity of dye afforded by the ſhell fiſh, from each of which not more than a ſingle drop was obtained. For 50lb. of wool they uſed no leſs than 200lbs. of the liquor of the buccinum, and 100lbs. of that of the purpura, or 6lbs. of liquor to 1lb. of wool. We ought not to be much ſurprized, therefore, that this colour vied in value even with gold itſelf. The ancient writers diſtinguiſh many different ſhades of purple. One of them, which was very dark, appears to have been a kind of violet, inclining towards a reddiſh hue. " Nigrantis roſæ colore

fubluens," Pliny, lib. 9. sec. 50. Another, less esteemed, was a kind of crimson. "Rubens color, nigrante deterior," lib. 9. sec. 62. The most valued of all, and in which the Tyrians particularly excelled, was a deep red purple, of the colour of coagulated blood. "Laus ei summa in colore sanguinis concreti," Pliny, ibid. It is in allusion to this that Homer and Virgil give to blood the epithet *purple*. There was a fourth kind known in later times, very different from those we have spoken of. The colour was whitish; an account of which may be seen in Perrault's translation of Vitruvius.

The purple has been almost every where a mark of distinction attached to high birth and dignity. It was an ornament of the first offices of Rome; but luxury, which was carried to great excess in that capital of the world, rendered the use of it common among the opulent, till the emperors reserved to themselves the right of wearing it. Soon afterwards it became the symbol of their inauguration. They appointed officers to superintend the manufactories, principally established in Phœnicia, where it was prepared solely for their use. The punishment of death was decreed against all who should have the audacity to wear it, though covered with another colour. The penalty, so tyrannically denounced against this whimsical species of treason, doubtless occasioned the loss of the art of dyeing purple; first in the West, but much later in the East, where it flourished considerably till the eleventh century.

It appears that some kinds of purple preserved their colour for a very long time. Plutarch, in his life of Alexander, relates that the Greeks found in the treasury of the king of Persia a great quantity of purple which had not lost its beauty, though it was 190 years old.

It is commonly asserted, on the authority of most of the ancient writers, that the purple had a very strong and disagreeable odour. It would appear, however, from Pliny, lib. 9. sec. 36. that this was the case only with some particular kinds. After extolling the beauty of the true purple, and allowing that it was justly an object of ambition, he asks, how it happens that the other kinds of purple, obtained from the shell-fish called *conchylia*, should be so high priced, considering the stinking disagreeable odour which the stuffs have that are dyed with them.

After all, the boasted purple of antiquity was a miserable dye compared with many which we now possess, and affords a strong proof of the imperfect state of the art at the period when it was held in such esteem. It was, no doubt, the most rich and brilliant colour then known.

It is a curious fact, that Mr. Bruce, whose acquaintance with ancient authors ought to have convinced him of the contrary, maintains that the Tyrian purple was produced with cochineal, and that the story of its being the blood of a shell-fish was invented and propagated by the Tyrians with a view of deceiving other nations, and keeping the art of dyeing this colour exclusively to themselves. He even adduces this as a proof of the early intercourse carried on with the new world, in times long antecedent to those in which we suppose the discovery of the continent of America was first made.

The ancients obtained from the *coccus*, now known by the name of kermes, a colour which was almost as highly esteemed as purple, and which was sometimes mixed with it. Pliny informs us it was employed in the preparation of the imperial robes. It was generally called scarlet, and was sometimes confounded with the purple. The use of the coccus in dyeing is very ancient, since it appears from the commentators, to be alluded to in Exodus, chap. xxxix. ver. 1. and 28.

Our materials for a history of the art of dyeing, during the ages of classical antiquity, are very scanty. Amongst the Greeks the useful arts were degraded even in the eyes of philosophers, and this contempt descended to the Romans; for Pliny, speaking of dyeing, avowedly neglects the description of operations which are unconnected with the liberal arts. "Nec tingendi rationem omisissimus, si unquam ea liberalium artium fuisset."

The art of dyeing among the Greeks appears to have made no great progress; the dress of the people was of cloth which had received no dye, and which might be washed. The rich preferred coloured clothes; they esteemed such as were dyed scarlet with the kermes, but they valued still more highly those of purple.

The few details relative to dyeing into which Pliny has entered in his great work, are almost wholly confined to the purple, of which we have given an account. The few scattered facts to be met with, that serve at all to illustrate the history of the art, we shall briefly notice. Some varieties of colour, derived from the purple, and produced by different mixtures of the various kinds of shell-fish, and also by admixture with the dye of the coccus, or kermes, appear to have been fashionable in Pliny's time. These originated, according to our author, in the errors and failure of the dyers, who having, in the first instance, spoiled their cloth, endeavoured to hide the defects by giving it another shade: hence arose those compound twice-dyed colours which were soon held in high repute.

Besides the Tyrian purple, scarlet, and the varieties and compounds of those colours, Pliny mentions yellow as a very ancient dye, and highly esteemed in former times. The veil which the bride wore on her wedding day was of yellow, and none but women were permitted to use it. They had also a colour resembling the cyanos, or blue-bottle, and another like the golden yellow flower elichryson. None of these colours, says Pliny, were known, or at least in request in the days of Alexander the Great; for the Greek writers, who wrote soon after his decease, make no mention of them. They are evidently, however, of Greek origin, as appears from their names, which, though Greek, were current in Italy in Pliny's time.

The use of vegetable dyes appears to have been in a great measure unknown to the Romans; though the inhabitants of Gaul, according to Pliny, imitated all colours, even the Tyrian purple and the scarlet, with the juice of certain herbs. In the eleventh chapter of the thirty-fifth book of Pliny's history, is preserved a valuable notice of the process followed by the Egyptians in dyeing linen. They stained, says he, white cloth, not with colours, but with certain drugs, which have the property of absorbing them, but which exhibit no appearance of any dye till they have been boiled some time in a cauldron, from which they are withdrawn painted or stained of various colours. What is most extraordinary, says Pliny, is, that the cauldron containing only colour of one kind should impart to the cloth shades of various hues according to the nature of the drugs which were laid on, and the colours are so fixed that they can never be washed out, but are more durable and fixed than if they had never been immersed in the boiling dye.

We have here a tolerably accurate description of the process of calico printing; and the only mention in any ancient author of an art which has existed for ages past in the East, and is practised there at this day, probably with little variation from the mode described by Pliny.

The art of dyeing linen appears not to have been known in Greece before Alexander's invasion of India, where they

dyed the sails of his vessels of different colours. The Greeks seem to have borrowed this art from the Indians.

We may form some idea of the state of the art of dyeing amongst the Romans, from the enumeration of the different colours which were in use, and the substances employed in producing them. In addition to those enumerated by Pliny, we find, that in the equestrian games of the circus, the different divisions were distinguished by the colours *green*, color prasinus; *orange*, rufatus; *grey*, venetus; and white. We shall enumerate, after Mr. Bischoff, who has minutely examined the subject, the ingredients employed at that time in the art of dyeing, in addition to the two important ones already mentioned, the purple fish and coccus.

1. Alum. It is probable, from what we shall state hereafter, that the ancients were unacquainted with our alum in its state of purity.

2. Alkanet. Suidas says, that this substance was also used by women as a paint.

3. The blood of birds, which was used amongst the Jews.

4. The fucus; that of Crete was preferred, and it was generally employed as a ground or preparative for valuable colours.

5. Broom.

6. The violet, from which the Gauls prepared a kind of purple.

7. Lotos medicago arborea; snail trefoil; the bark was used in dyeing skins, and the root in dyeing wool.

8. The bark of the walnut-tree and the peel of the shell.

9. Madder. We are not certain whether the madder of the ancients was the same as ours, or another root of the same tribe.

10. Woad (glastum). This plant was undoubtedly in use among the ancients, but we do not know whether their preparation of it was the same as ours.

We are not to infer, however, that these were the only substances employed by the ancients in the art of dyeing; many more being, in all probability, in use, of which we have no account. Indigo (indicum nigrum) is mentioned by Pliny, and though some doubts have been entertained by his commentators respecting the true nature of this substance, some supposing it to have been Indian ink, yet it is very evident he meant the indigo of the moderns, from the purple smoke which he says it emitted when set on fire, and which we believe is peculiar to indigo. It was never, however, we believe, employed in dyeing, but simply as a pigment.

India was the nursery of the arts and sciences, which were afterwards spread and perfected among other nations. Accidents, which had a tendency to improve the art, could not fail to be multiplied rapidly in a country rich in natural productions, which requires little labour for the support of its inhabitants, and the population of which was favoured by the bounty of nature and the simplicity of manners, till it was opposed by the tyranny of succeeding conquerors. But religious prejudices, and the unalterable division into casts, soon put shackles upon industry; the arts became stationary, and it would seem that the knowledge of dyeing cotton in that country was as far advanced in the time of Alexander as it is at present.

The beautiful colours which we observe in their printed calicoes, would lead us to suppose that the art of dyeing had then attained a high degree of perfection, yet we find, from the details of those who have witnessed their operations, that the Indian processes are so complicated, tedious, and imperfect, that they would be impracticable in any other country, on account of the difference in the price of labour. The art of printing calicoes has been practised in India at least twenty-two centuries; for the historians of Alexander's invasion of that ill-fated country speak of their flowered cloths or chintz. If they excelled therefore in the richness and brilliancy of two or three colours; it is to be attributed to the superior quality of some of their dyes, peculiar to their own country, the effect of which was perhaps heightened by the length and multiplicity of their operations. The knowledge of this art appears to have spread over a considerable part of Asia. It was practised, and is to this day, by the Persians; and we have seen that in Pliny's time, it was established in Egypt.

From the fifth volume of the "Memoires concernant l'Histoire, les Sciences, les Arts, les Mœurs, &c. des Chinois," it appears, that wool was never worn in China but as a substitute for fur, and that cotton and silk, being the only substances ever dyed by the inhabitants, received all their colours from vegetable tingent matters; that their colours were principally red, blue, violet, and what is called a woad colour; and that under the three first dynasties the business of dyeing was chiefly practised by the female part of each family, for its own particular use; and it probably continued to be practised without any thing like principle or science until near the end of the seventh century, when the Chinese discarding their own, borrowed the art and means of dyeing which were then in use among the Indians and Persians; and it is said, that alum and copperas, which the Chinese did not use before, were among the means so borrowed; a fact which renders it probable, that there was little, if any thing, in the Chinese art of dyeing, of which the loss need now be regretted.

It appears, however, that long before this time a knowledge of the uses of alum and of iron in dyeing had spread from Hindoostan and Persia westward to Egypt, and thence to Greece and Rome. Bergmann, indeed, and after him, Beckmann, have represented the alum of the ancients as different from the crystallized salt of the moderns; and have supposed that the varieties of alum mentioned by Dioscorides, were stalactites, containing but little alum, and consisting chiefly of calcareous earth. Nature, however, does produce some, though but little, crystallized alum, particularly in Egypt and some parts of Asia; and it probably was in this state that its good effect in dyeing had been first observed, before mankind were led to the means and operations since employed for separating and collecting it from the various aluminous ores. Bergmann informs us, that the factitious salt which is now called alum, was first discovered in the eastern countries, and that among the most early works established for the preparation of alum, we may justly number that of *Roccho*, a city in Syria, now called Edessa, hence the appellation of *roch alum*. He adds, that Bartholomew Perdix, or Pernix, a merchant of Genoa, who had been at Roccho, discovered the matrix of alum in the island of Ischia, about the year 1459, and established a manufactory there; at the same time, John de Castro, who had visited the manufactories at Constantinople, discovered a matrix at Tolfa, by means of the ilex aquifolium, which he had also observed to grow in the adjacent mountains of Turkey; and his opinion was confirmed by the taste of the stones. The attempts made by the Genoese at Viterbium and at Volaterre succeeded extremely well; and the preparation of it in Italy soon increased wonderfully fast. The first manufactory of alum in England was established in the reign of Elizabeth, at Gisborough, by one Thomas Chaloner.

In the fifth century all the arts were lost throughout the West, except a few, which in a state of decay were preserved

in Italy; and no traces were left of knowledge, induſtry, or humanity.

Muratori quotes a manuſcript of the eighth century, in which we find a deſcription of ſome dyes, principally for ſkins, and ſome proceſſes connected with the arts; but the Latin, which is almoſt unintelligible, and the chaſms we find here and there, prevent us from being able to form a juſt idea of theſe proceſſes.

The arts were better preſerved in the Eaſt, where articles of luxury were procured by ſome of the great, even ſo late as the twelfth century. During the cruſades, the Venetians derived their power from the barbarous mania of the age: their commerce increaſed; the arts were eſtabliſhed among them, and improved by the induſtry of the Greeks, and ſpread from thence through the other parts of Italy. In the year 1338, Florence contained two hundred manufacturers, who are ſaid to have made from ſeventy to eighty thouſand pieces of cloth, which, as an object of commerce, were worth twelve hundred thouſand crowns of gold.

It is ſaid that archil was accidentally diſcovered by a Florentine merchant, about the year 1300. Having obſerved that urine imparted a very fine colour to a certain ſpecies of moſs, he made experiments, and learned to prepare archil. He kept his diſcovery ſecret a long time; his poſterity, a branch of which ſtill exiſts, according to Dominique Manni, have retained the appellation of Ruccellai, from oreiglia, the Spaniſh term for that kind of moſs.

The arts continued for a long time to be cultivated in Italy with increaſing ſucceſs. In the year 1429, the firſt collection of the proceſſes employed in dyeing appeared at Venice under the name of "Mariegola del' arte dei tentori;" a ſecond edition, much improved, came out in 1510. A certain perſon, named Gioran Ventura Roſetti, formed the deſign of rendering this deſcription more uſeful and extenſive. He travelled through the different parts of Italy, and the adjacent countries, where the arts had begun again to flouriſh, in order to make himſelf acquainted with the various proceſſes employed, and he publiſhed, under the title "Plictho de l'arte de tentori," &c. a collection which, according to Mr. Biſchoff, is the firſt that united the different proceſſes, and which ought to be regarded as the leading ſtep toward the perfection which the art of dyeing has attained. This work was printed at Venice, in 1548; a French tranſlation of it appeared at Paris in 1716. It is remarkable that in the work entitled "Plictho," not a word is ſaid either of cochineal or indigo; from which we may conclude that theſe two dyes were either unknown or not employed at that time in Italy.

The firſt indigo uſed in Europe appears to have been brought from the Eaſt Indies by the Dutch. India was doubtleſs the country where that valuable ſubſtance was firſt produced. The uncivilized inhabitants of other countries have, indeed, diſcovered modes of obtaining colouring matter, very nearly reſembling that of indigo, from other plants, as the iſatis tinctoria, or woad, and the genipa americana, but they obtained theſe matters in a liquid form only, and employed them in their recent ſtate.

The natives of India, however, went farther, they precipitated and collected, in a dry ſolid form, the colouring matter of indigo, and diſcovered the means of afterwards diſſolving and applying it to ſtuffs. In Africa, the Mandingo negroes, according to Mr. Park, dye their cloth of a laſting blue colour, by the following ſimple proceſs. The leaves of the indigo, when freſh gathered, are pounded in a wooden mortar, and mixed in a large earthen jar, with a ſtrong ley of wood aſhes; chamber-lye is ſometimes added. The cloth is ſteeped in this mixture, and allowed to remain until it has acquired the proper ſhade. In Kaarta and Ludamar, where indigo is not plentiful, they collect the leaves and dry them in the ſun, and when they wiſh to uſe them, they reduce a ſufficient quantity to powder, and mix it with the lye as before. "Either way," ſays Mr. Park, "the colour is very beautiful, and equal to the beſt Indian or European blue." The uſe of indigo was known to the Mexicans before the arrival of the Spaniards, and Clavigero, in his hiſtory of that country, gives an account of the method of obtaining it. Hernandes had long before deſcribed the plant as being indigenous in Mexico, and employed by its ancient inhabitants; and Ferdinand Columbus, in his "Life of Chriſtopher Columbus," mentions it as one of the native plants of Hiſpaniola. What the abbé Raynal therefore aſſerts, of its being tranſplanted from the Eaſt Indies to America, can be true only of one ſpecies, the indigofera tinctoria, Linn. The manufacture of indigo, however, was not eſtabliſhed in America till ſome time after the diſcovery of that country; and on the plant which produces it being recognized by the Portugueſe in Brazil as identical with that from which indigo was extracted in the Eaſt Indies. The uſe of indigo, which was a great acquiſition to the art of dyeing, was not eſtabliſhed without conſiderable difficulty. It was ſtrictly prohibited in England in the reign of Elizabeth, as was alſo logwood, which was ordered to be burned if found in any manufactory. This prohibition was not taken off till the reign of Charles II.

In like manner the uſe of indigo was proſcribed in Saxony, in the edict againſt it, which brings to one's mind the edict againſt the employment of antimonial emetics; it is ſpoken of as a highly corroſive colour. This is a ſtriking example of the errors into which an unenlightened adminiſtration may fall, which liſtens to the ſuggeſtions of intereſted individuals. Thoſe who dyed blue, and were accuſtomed to uſe paſtel and woad, repreſented that indigo would deſtroy the ſale of thoſe two articles, which were the produce of the country. Such a reaſon, which would appear ſpecious to many, even in the preſent day, eaſily produced a prohibition which would be ſoon eluded by paying a tribute to the induſtry of other nations. The prejudice againſt indigo was likewiſe communicated to France, and Colbert's inſtructions forbade the uſe of more than a certain quantity in the paſtel vats.

Cochineal was another important acquiſition to the art of dyeing, for which we are indebted to the firſt conquerors of Mexico. The Spaniards, having obſerved that the inhabitants of Mexico employed cochineal in painting their houſes and dyeing their cotton, gave their government an account of the beauty of the colour; and Cortes, in the year 1523, was ordered to promote the increaſe of the valuable inſect from which it is obtained. The natural colour, however, which the cochineal gives, is but a dull colour. Soon after cochineal was known in Europe, a great chemiſt of the name of Kuſter, Kuffler, or Kepfler, found out the preſent proceſs for dyeing ſcarlet by means of a ſolution of tin, and carried the ſecret to London in the year 1543. See Cochineal and Scarlet.

The ancients applied the name ſcarlet to the colour obtained from kermes, which was much inferior in beauty to the colour we diſtinguiſh by that appellation. We probably know how to employ the kermes to greater advantage than they did, ſince we poſſeſs a pure alum which diſpoſes the ſtuff to receive a more beautiful and durable colour; yet our dyers have almoſt entirely diſcontinued the uſe of it, becauſe they can obtain from cochineal a colour beyond all compariſon more beautiful. The ſuppoſition, that the

colour which we obtain from kermes is preferable to that obtained by the ancients, is supported by the testimony of Pliny, who insinuates that it was not a durable colour; now the colour we give by means of kermes to wool prepared with alum, is exceedingly durable. The discovery of scarlet may be considered as the most important era in the art of dyeing, as it introduced to our knowledge the solution of tin, since so variously and happily applied. A Flemish painter, called Gluck, got possession of this secret, and communicated it to Gobelin. The knowledge of the process afterwards spread throughout all Europe. Gluck travelled into the East, where there were still some remains of Grecian industry, and afterwards settled in Flanders, where he spent a long and prosperous life. According to Mr. Francheville, this man, who had been so useful to his country, died about the year 1550.

For a long time Italy, and especially Venice, possessed the art of dyeing almost exclusively; a circumstance which contributed to the prosperity of their manufactures and commerce: by degrees it was introduced into France. Giles Gobelin, to whom the process for making the true scarlet had been communicated, established a manufactory in the place which still bears his name; and this undertaking was deemed so rash, that it was termed *Gobelin's folly*.

The attention of the Royal Society appears to have been early directed to the improvement of the art of dyeing. At a meeting of that learned body on the 30th of April, 1662, Mr. Hook was desired to translate into English, a work on dyeing, which appears to have been that already mentioned under the title of Plictho. On the same day also, sir William Petty, one of its earliest and most active members, in consequence of a previous request from the society, brought in "An Apparatus to the History of the common practices of Dyers," which was afterwards printed in "Dr. Spratt's History of the Royal Society," and seems to have been the first work published in the English language on the processes and operations of dyeing. Nearly two years afterwards Mr. Boyle presented to the society his "Experiments and Considerations touching Colours." And on the 10th of August, 1664, it was ordered by the society, "that the way of *fixing colours* should be recommended to Mr. Howard, Mr. Boyle, and Dr. Merritt." These, and especially the two first, were amongst the most distinguished members of the society; but it does not appear that any thing deserving of notice was done in consequence of this recommendation. However, at a meeting of the society on the 11th of November, 1669, that very ingenious and useful member, Mr. Hook, produced a piece of calico stained after the way contrived by himself, which he was desired to prosecute in other colours besides those that appeared in this piece; and accordingly on the 9th of the following month, Mr. Hook produced another specimen of staining with yellow, red, green, blue, and purple colours, which he said would endure washing with warm water and soap. But from this time it does not appear that any thing considerable was done for nearly the space of a century by men of science in this country towards the improvement of the arts of dyeing and calico printing.

In France, however, the minister Colbert, anxious to extend the commerce and manufactures of his country, which had languished during the stormy administrations of Richlieu and Mazarin, turned his attention particularly to the art of dyeing. He invited the most skilful artists, rewarded their talents, and established many manufactories; and it is curious to remark, that those of Vaurobais and Sedan were called, in the letters patent which were granted them, manufacturers of fine cloth after the Dutch and English fashion. In 1672, he published a Table of Instructions for Dyeing, under the title of "General Instructions for dyeing Wool and woollen Manufactures of all Colours, and for the Culture of the Drugs or Ingredients employed in them." This, however, was not intended merely to diffuse information, but as a legislative act, to controul the dyers in their operations. This work merits attention; we shall first notice the reason which he gives for considering the subject as one of great importance.

"If," says Colbert, "the manufactures of silk, wool, and thread are to be reckoned amongst those which most contribute to the support of commerce, dyeing, which gives them that striking variety of colour by which they resemble what is most beautiful in nature, may be considered as the soul of them, without which the body could scarcely exist. Wool and silk, the natural colour of which rather indicates the rudeness of former ages, than the genius and improvement of the present, would be in no great request if the art of dyeing did not furnish attractions which recommend them even to the most barbarous nations. All visible objects are distinguished and recommended by colours, but for the purposes of commerce it is not only necessary that they should be beautiful, but that they should be good, and that their duration should equal that of the materials they adorn."—But Colbert, though he instituted many useful regulations for the instruction of the farmer and the artist, imposed a system of prohibition and restraint so excessive, as almost to bar all future improvement. He divided the dyers into two classes, to one of which were confined the colours deemed durable and fixed, whilst the other class was allowed only to meddle with those which were considered fugitive. In the dyeing of black cloth he insisted that the operation should be begun by the dyers in grain, or those who gave the durable colour, and finished by those who produced the false one. Each was confined to a certain number of ingredients, and neither were suffered to have Brazil wood, and various other articles. The bad effects of this prohibition were moderated by the facility of eluding it, and by the rewards bestowed on those whose experiments promoted the progress of the art, and whose discoveries were afterwards to be published, and to modify the existing regulations.

French industry lost its pre-eminence by the criminal revocation of the edict of Nantz, which carried desolation into her manufactories, and dispersed her workmen, and the knowledge of her arts, throughout all Europe.

Since that time the department of administration, charged with the superintendence of the arts and manufactures, has constantly sought to repair those errors, and to encourage industry and exertion by the diffusion of knowledge, which, under wise laws, is the most efficacious means that can be employed.

Dufay, Hellot, Macquer, and Berthollet, have been successively charged with the care of improving the art of dyeing; and to their labours all Europe is indebted for most valuable acquisitions.

Dufay amended, or rather superseded, the "Instructions, &c." of Colbert, by the publication of a new one, under the administration of M. d'Orry, in 1739. He appears to have been the first who entertained just, though incomplete, ideas of the true nature of colouring substances, and the cause of their adhesion to stuffs when dyed. In his "Observations physiques sur le melange de quelques couleurs dans le tincture," Mem. de l'Academ. 1737, he observes, that colouring particles are naturally disposed to adhere, more or less firmly, to the filaments which receive them; and he remarks very justly, that without this disposition

stuffs would never assume any colour but that of the bath, and would always divide the colouring particles equally with it; whereas the liquor of the bath sometimes becomes as limpid as water, giving out all the colouring matter to the stuff, "which seems to indicate," says he, "*that the ingredients have less attraction for the water than for the particles of the wool.*" He also noticed, *the difference in the degree of attraction which different substances, as wool and cotton, exert on the same colouring matters*, and which he found so great, that a skain of each having been in an equal degree subjected to the operation for dyeing scarlet, the woollen yarn was found to be fully and permanently dyed, while the cotton retained all its former whiteness. Yet these facts, important as they were, to the foundation of a theory of the art of dyeing, were unproductive in his hands; for though satisfied with the explanation they offered of many phenomena, yet they left, says he, so much to be wished for, that he would relinquish it readily, if a more probable one could be found. He appears to have had no idea of the other and more important cause of the permanency of colours, that which arises from the use of mordants, or the interposition of a suitable basis, possessing a particular attraction both for the colouring matter and dyed substance, and acting as a bond of union between them. He examined, with great sagacity, certain processes, and established the surest methods that could at that time be employed for determining the goodness of a colour, and this he did in an easy and familiar manner. His labours, on the whole, entitle him to the gratitude of posterity, and he may justly lay claim to the merit of having first discovered and enunciated the facts, and of having drawn some partial conclusions from which the true theory of dyeing was some years afterwards clearly and luminously deduced.

He was succeeded by Hellot, to whom we are indebted for one of the best practical treatises on the art of dyeing wool and woollen cloths now extant. This work is valuable for the accuracy with which the numerous processes are described: without profiting, however by the hints thrown out by his predecessors, he suffered himself to be misled by a vague and groundless hypothesis, on the cause of the adhesion of the colouring particles to the substance dyed, the action of mordants, and the difference between the true or durable, and false or fading dyes. Of his theoretical ideas, and the principles he laid down, some judgment may be formed from the following passage taken from his work. "I believe it may be laid down as a general principle in the art of which I am now treating, that all the invisible mechanism of dyeing consists in dilating the pores of the body to be dyed, in depositing in them particles of foreign matter, and retaining them there by a kind of covering not liable to be affected by water, rain, or the rays of the sun; in choosing colouring particles of such a degree of fineness as to be rendered sufficiently fixed in the pores of the stuff opened by the heat of boiling water, and again constricted by cold, and also coated by the kind of varnish which the salts, employed in its preparation, had left in those pores; whence it follows that the pores of the fibres of the wool which has been wrought, or is to be wrought into cloth, should be cleansed, enlarged, coated over, and then constricted, so that the colouring particles may be retained in them nearly in the same manner as the diamond is retained in the collet of a ring." He fancied that he could discern in every dyeing process some means by which sulphate of pot-ash, then called vitriolated tartar, might be formed; and this neutral salt not being readily soluble by cold water, nor air, nor light, he conceived the whole art of dyeing to consist in first dilating the pores of the substance to be dyed, so as to procure a copious admission of colouring matter, divided by a suitable preparation into atoms, and then wedging or fastening these atoms within the pores of the dyed substance, by the small particles or crystals of this difficultly soluble salt. Upon this *mechanical* hypothesis, he supposed that alum became useful in dyeing, not by the pure clay or alumine which it contains, but by furnishing sulphuric or vitriolic acid, to assist in forming the sulphate of pot-ash, which was to perform the important function of wedging or fastening the colouring atoms. But though nothing could be more groundless than such a theory, the learned in all countries appear to have been satisfied with it for a considerable length of time, it being always less troublesome to believe than to make experiments.—Macquer followed next. He has given us an exact description of the processes employed in dyeing silk, and his practical treatise, published in 1763, is held in deserved estimation. He has made us acquainted with the combinations of the colouring principle of Prussian blue; he has endeavoured to make an application of it to the art of dyeing, and has given us a process for communicating the most brilliant colour to silk, by means of cochineal. Macquer intended to have published a general treatise on the art of dyeing, the prospectus of which he issued in the year 1781, but the indisposition which so long preceded his death, prevented his engaging in it, and he died in 1784, before he had been able to carry into effect any part of his plan. It is surprising that Macquer, who was an excellent chemist, and amongst the first who entertained correct ideas of the nature of chemical affinity should have been seduced by the hypothesis of Hellot. "I should now," says he in his treatise on dyeing silk, "explain the action of mordants, and unfold the causes of durable and fading dyes; but this subject has been treated with such sagacity by Mr. Hellot, that I shall refer the reader to him." Bergmann seems to have been the first who referred the phenomena of dyeing *entirely* to chemical principles. Having dyed some wool and silk in a dilute solution of indigo in sulphuric acid, he explains the effects he observed in the operation, by attributing them to the precipitation occasioned by the blue particles having a stronger attraction for the particles of the wool and silk than for those of the acidulated water: he remarks, that this attraction of the wool is so strong as to deprive the liquor entirely of the colouring particles, but that the weaker attraction of the silk can only diminish the proportion of those particles in the bath; and he shews that both the durability of the colour, and the degree of intensity it is capable of acquiring, depend on these different attractions. This is the true light in which the phenomena of dyeing, which are purely chemical, should be considered. Dufay had advanced thus far, but overlooked the importance of his own simple truths, in the search after more recondite and complicated causes. But the peculiar action of mordants was still unexplained, except on the wild hypothesis of Hellot, till our countryman Mr. Keir, the ingenious translator of Macquer's Chemical Dictionary, suggested, "that in dyeing, the earth of alum was precipitated, and in this form attached to the material prepared or dyed." Macquer soon after adopted the opinions of Bergmann and Keir, and in the second edition of his dictionary, under the article *Dyeing*, published in 1778, treated the subject in a more extended manner, and proved that he had formed just conceptions of the nature and uses of alum, and of different metallic solutions, as mordants in dyeing. Berthollet succeeded next to the place of trust which had been successively held by Dufay, Hellot, and Macquer, a post which he has held, and still holds, with distinguished honour to himself, and

advantage to his country. In a series of memoirs, inserted in the Transactions of the academy, the Annales de Chimie, and Journal de Physique, he has examined various points of chemical theory connected with the art of dyeing, and almost all his labours have since been directed to this object. In 1791, he published his elements of the art of dyeing in 2 vols. 8vo. a work which has contributed more to the progress of true theory and the general improvement of the art, than any other treatise whatever. This work has been translated into English by Dr. Hamilton, and a second edition of the original, with considerable additions, appeared in 1803. Every thing which a liberal and enlightened government could do for the encouragement and progress of the art, has been done in France, and this solicitude has been crowned with the success it merited. Mr. Anderson attributes the superiority which certain articles of French manufacture maintain over those of other nations, who possess the most beautiful wool, to the perfection of their dyes; and Mr. Home is of opinion, that the French are indebted to the academy of sciences for their superiority in many of the arts, and especially that of dyeing. Perhaps another cause of the alleged superiority of the French over other nations in the art of dyeing, may be discovered in the peculiar nature of their manufactures. Silk, of all other substances, seems best adapted to the display of fine and brilliant dyes, and it constitutes, in all its various forms, a large portion of the manufactures of France. We may look, therefore, to the dye-houses of Lyons, as well as to the academy of sciences, for the cause of that superiority which is now gradually declining. We have already spoken of our countryman Mr. Keir, as the first who suggested the true theory of mordants, which was afterwards extended and improved by Macquer. The worthy president of the literary and philosophical society of Manchester, Mr. Henry, some time after, read a paper to the society, since published in the 3d volume of their Memoirs, "On the nature of wool, silk, and cotton, as objects of the art of dyeing; on the various preparations and mordants requisite for these different substances, and on the nature and properties of colouring matter." This paper, which is replete with new and ingenious views of the nature and objects of dyeing, may be considered as amongst the first attempts in this country to reduce to system and theory the subject of which it treats: Mr. Henry, in these Memoirs, first pointed out the peculiar nature of the aluminous mordant of the calico printers; he shewed that by double decomposition an acetite of alumine was formed, and explained the cause of its superiority over the sulphate of alumine, which consists in the substitution of a volatile vegetable acid in lieu of the sulphuric.

In the year 1794, Dr. Bancroft published his "Experimental Researches concerning the philosophy of permanent colours, and the best means of producing them by dyeing, calico printing, &c." which may be considered as the first, and indeed only original work on the subject which this country has produced. This work, as the title indicates, is rather an experimental than practical treatise: it contains, however, much valuable information, which the practical dyer may apply in many cases with considerable advantage, and is also useful as containing a history of all the different substances of which it treats, and an account of the labours of Macquer, Dufay, Hellot, Berthollet, and others, in this field of science. It is to be regretted, that the work is still imperfect, the first volume only having yet appeared. The second, which was intended to comprehend all the remaining adjective colours and colouring matters, not treated of in the first, particularly those very interesting ones which are derived from the tribe of madders, can hardly, after an interval of fifteen years, be looked for with confidence.

Dr. Bancroft first pointed out the true action of tartar in the process for dyeing scarlet, and clearly proved that the nitro-muriate of tin, or any solution of tin alone, produced a crimson only; and that the addition of tartar produced a scarlet, by the conversion of a portion of the crimson colouring matter of the cochineal, to a pure yellow. On this observation he founded an improvement in the scarlet dye, which consisted in communicating to the cloth, by means of quercitron bark, and any suitable mordant, such a shade of yellow as would produce, with the crimson of the cochineal, a true scarlet. By this process he expected to save all that cochineal which he conceived to be expended in the production of the yellow: the trials on the large scale, however, we are informed by Dr. Bancroft, did not justify the expectations he had formed, of the importance of the process.

A more important and lasting service, however, he has rendered to the art of dyeing, by the introduction of the quercitron bark, a drug which is now become of such general and acknowledged utility, as to supersede almost every other kind of yellow colouring matter whatever. For the history of this substance, and other particulars respecting its introduction, we must refer to the article itself, under the head QUERCITRON BARK.

Though we have to record no brilliant discoveries or improvements in the practice of dyeing, within these few years, yet the art has continued progressively to improve, the different processes have been simplified and amended; and what some years ago was considered a matter of chance and uncertainty, is now reduced to fixed principles.

The dyeing of Turkey red is now fully understood and practised in this country, with a success at least equal to that of any other. The process has, with some modifications, been applied lately to the dyeing of piece goods, and the red thus produced surpasses in beauty and durability, all other colours which it is possible to fix on cotton. But it is not our intention here to enter into a history of all the minor improvements that have been made in the art of dyeing; they will be treated of at large, during the progress of the work, under their respective heads.

DYEING, *the Laws relating to*, are as follow: Dyers shall dye both the cloth and the list, or forfeit it. 1 R. III. cap. 4. No dyer may dye any cloth with archil, or with brazil, to make a false colour in cloth or wool, &c. on pain of twenty shillings. Stat. 3 & 4 Edw. VI. cap. 2. Dyers are to fix a seal of lead to cloths, with the letter *M*, to shew that they are well maddered, &c. or forfeit three shillings and fourpence; and not to use logwood in dyeing on pain of forfeiting twenty pounds. Stat. 23 Eliz. cap. 9. And penalties are inflicted on dyers, who dye any cloths deceitfully, and not being dyed throughout with wood, indigo, and madder; also marks shall be put to the cloth dyed, &c. Dyers in London are subject to the inspection of the Dyers' company, who may appoint searchers; and out of their limits, justices of peace in sessions to appoint them: opposing the searchers incurs ten pounds penalty, by stat. 13 Geo. I. c. 24.

DYEING, in a more extensive sense, is applied to all kinds of colourings given to bodies of any sort.

In which sense, dyeing amounts to the same with *coloration;* and includes staining, painting, gilding, marbling, printing, &c. The Chinese are said to practise the dyeing of tea with catechu, which gives the worst sorts of green tea leaf the colour, and its infusion the tincture of bohea. Short. Differt. on Tea, pref. p. 15. See TEA and CATECHU.

The ſorts of dyeing now commonly uſed in vulgar trades, are 1. Whitening of wax, and ſeveral ſorts of linen, and cotton cloths, by the ſun, air, and reciprocal effuſions of water. See BLEACHING. 2. Staining of wood and leather by lime, ſalt, and liquors, as in ſtaves, canes, marble, leathers, marquetry, &c. 3. Marbling of paper by tempering the colours with ox-gall, and applying them upon a ſtiff-gummed liquor. See PAPER. 4. Colouring, or rather diſcolouring ſilks, tiffanies, &c. by brimſtone. 5. Colouring ſeveral iron and copper works into black with oil. 6. Giving leather a gold colour, or rather dyeing ſilver-leaves like gold, by varniſhes; and in other caſes by urine and ſulphur. 7. Staining of marble and alabaſter, with heat, and coloured oils. 8 Tinging ſilver into braſs with brimſtone or urine. 9. Colouring the barrels and locks of guns blue and purple with the temper of ſmall-coal heat. 10. Colouring glaſs cryſtals, and earthen-ware with the ruſts and ſolutions of metals. See POTTERY, &c. 11. Colouring live hair, as in Poland, both horſe and man's hair; and alſo of furs. 12. Enamelling and annealing. See ENAMELLING. 13. Application of colours, as in the printing of books and pictures; and the making of playing cards, japanning, &c. See PRINTING, CARDS, and JAPANNING. 14. Gilding and tinning with mercury, block tin, and ſal ammoniac. See GILDING and TINNING. 15. Colouring metals, as copper with calamine into braſs, and with zinc or ſalt-petre into falſe gold, or into falſe ſilver with arſenic. See CALAMINE, BRASS, ZINC, ARSENIC, &c. 16. Making painters' colours, by preparing of earth, chalk, and ſlates, as in umber, oker, Cologn earth, &c. out of the calces of lead, as ceruſs and minium; by ſublimates of mercury and brimſtone, as in vermillion; by tinging of white earths variouſly, as in verditer, and ſome of the lakes; by concrete juices or fæculæ, as in indigo, pinks, ſap-green, and lakes: and by ruſts, as in verdigris, &c. See CERUSS, MINIUM, VERMILLION, INDIGO, &c. 17. The applying of theſe colours by the adheſion of ox-gall, as in the marbled paper aforeſaid; or by gum-water, as in limning: or clammy drying oils, as the oils of linſeed, nuts, ſpike, turpentine, &c. See PAINTING, LIMNING, &c. 18. Watering of tabbies. See WATERING, CALENDER, TABBY, &c. Petty. Appar. Hiſt. of Dyeing, ap Sprat.

Glaſs dyed is the common matter of artificial jewels: the tinctures are given with zaffer, mangancſe, feretto, crocus martis, &c. The proceſſes are deſcribed at length in Antonio Neri, de Re Vitrario, lib. i. cap. 12, 13, 14, ſeq. See GLASS, GEM, &c.

The Peruvian women, when grown old, dye their grey hairs black by a very untoward operation, *viz.* holding the head ſome hours with the hair ſopped in a boiling tincture of the root of a tree called *cuchau*, by the Spaniards *maquey*.

DYEING *of Hats*, is done by boiling a hundred pounds of logwood, twelve pounds of gum, and ſix pounds of galls, in a proper quantity of water for ſome hours; after which about ſix pounds of verdigris, and ten pounds of green vitriol are added, and the liquor kept ſimmering, or of a heat a little below boiling. Ten or twelve dozen of hats are immediately put in, each on its block, and kept down by croſs bars for about an hour and an half; they are then taken out and aired, and the ſame number of others put in their room; the two ſets of hats are then dipped and aired alternately, eight times each; the liquor being refreſhed each time with more of the ingredients, but in leſs quantity than at firſt. This proceſs affords a very good black on woollen and ſilk ſtuffs as well as on hats. Com. Phil. Tech. p. 428. See HAT.

DYEING, or *ſtaining of wood, for inlaying, veneering, &c.* *Red* is done by boiling the wood in water and alum; then taking it out, adding brazil to the liquor; and giving the wood another boil in it. *Black*, by bruſhing it over with logwood boiled in vinegar, hot; then waſhing it over with a decoction of galls and copperas, till it be of the hue required. Any other colour may be given by ſqueezing out the moiſture of horſe-dung through a ſieve, mixing it with diſſolved roch alum, and gum-arabic; and to the whole adding green, blue, or any other colour deſigned. After ſtanding two or three days, pear-tree, or other wood, cut to the thickneſs of half a crown, is put into the liquor boiling hot, and ſuffered to remain till it be ſufficiently coloured. Park. Treat. of Japan. chap. xxvii. p. 82.

DYEING *of bone, horn,* or *ivory*. *Black* is performed by ſteeping braſs in aqua fortis till it be turned green: with this the bone, &c. is to be waſhed once or twice; and then put in a decoction of logwood and water, warm. *Green* is begun by boiling the bone, &c. in alum-water; then with verdigris, ſal ammoniac, and white wine vinegar; keeping it hot therein till ſufficiently green. *Red*, is begun by boiling it in alum-water, and finiſhed by decoction in a liquor compounded of quicklime ſteeped in rain-water, ſtrained, and to every pint an ounce of brazil wood added: the bone, &c to be boiled therein till ſufficiently red. Other methods are given by Salmon. And from him by Houghton. Park. lib. cit. p. 83. Salm. Polygraph. lib. iii. cap. 35. p. 275. Hought. Collect. N° 138. tom. i. p. 361. See BONES, HORN, IVORY, &c. The refuſe of the Bow-dye, given to hogs to feed on, is ſaid to tinge their very bones red.

Dynamometer

DYNAMOMETER, (from δυναμις, *power*, and μετρεω, *I measure*, meaning a measurer of power,) is the name of an instrument intended for measuring the muscular strength of men and other animals. An instrument of this kind was, some years ago, invented by Mr. Graham, and was afterwards improved by Dr. Desaguliers; but it was too bulky, and too limited in its use; so that it was soon neglected. Mr. Le Roy of the Academy of Sciences at Paris, constructed, soon after, a much more useful instrument for the same purpose. It consisted of a metal tube about a foot long, placed vertically on a foot like that of a candlestick, and containing in the inside a spiral spring, having above it a graduated shank terminating in a globe. This shank, together with the spring, sunk into the tube more or less, in proportion to the weight which pressed upon the globe at the top of the shank, and the graduation of the latter indicated the quantity of it. Therefore, when a man's strength was to be tried by means of this instrument, the man needed only press upon the above-mentioned globe with all his power, and the graduation of the shank indicated the quantity of that power, *viz*. it shewed the number of pounds weight to which it was equivalent.

Mr. Regnier, at Paris, at the instigation of Messrs. Buffon and Gueneau, contrived another sort of dynamometer. It consisted chiefly of an elliptical spring a foot long, and rather narrow. It was covered with leather, that it might not hurt the hand which compressed it. The strength of this spring was such as to exceed that of any animal to which it might be applied; and it contained an index with a mechanism which indicated how much it was compressed; or, which is the same thing, it indicated the quantity of the power which compressed the spring. Therefore, when a person wished to measure his power by means of this machine, he was obliged only to compress the elliptical spring with all his force, and to observe the quantity of that force as pointed out by the index of the machine. (See le Journal de l'Ecole Polytechnique, vol. ii.) Both the use and the construction of the last described machine were much extolled; but, upon a strict examination, it does not appear that it was superior to Le Roy's contrivance.

Since the above was made public, nothing peculiarly useful has been offered for the purpose of measuring the strength of animals. Yet upon the whole it seems, that the common well known spring steel-yard, though not intended expressly for that purpose, is the best instrument for measuring the strength of men and other animals. In principle, it is nothing more than Mr. Le Roy's contrivance; but under a much more commodious form. It has a ring at one end, and a hook at the other. By endeavouring to pull those parts from each other, a graduated rod comes out of the external tube, and shews the force which has been applied to it. Therefore, by fastening the ring to an immoveable object, and the hook to a man, or horse, &c. by means of a rope or otherwise, the strength of the man or other animal may be easily ascertained. See SPRING STEELYARD.

It certainly is a desirable thing to know the various muscular power of men and animals, especially of such as are to be employed for work of various kinds; and upon the whole a pretty good estimate may be obtained from the use of the above-mentioned machine. Yet, it must be observed, that a determination of this kind is influenced by a variety of circumstances, which tend to render the result inaccurate or equivocal. For instance, a man is much stronger than another man in his hands, whilst that other man is much stronger than the former in his legs. One can carry a great weight upon his head; another can pull a great weight after him, that is, drag it over the ground, and so forth. Nearly the same thing may be remarked with respect to other animals. But the most material circumstance is the duration of the exertion, *viz*. certain men, and especially such as are young and well fed, but not much used to work, are capable of immense exertion during a minute, or an hour, or even a day; but they are incapable of enduring a longer duration of labour; whilst others go on with a uniform daily exertion during weeks and years. The same variety in the length of the exertion takes place in other animals, especially such as are more commonly used for labour, *viz*. horses, mules, oxen, camels, &c.

Fig. 1. *Plate* XXVI. *Mechanics*, represents one of the whippletrees, to which two horses or oxen can be applied, the cover of the mechanism being removed to explain its internal structure. A A is the main whippletree, having a hook at *a* to back it to the plough, &c., and two others to connect it with two short whippletrees B, B, by which the cattle draw; the hook *a* is fastened to a straight bolt *b*, sliding freely through holes in two pieces of iron plate *d*, *f*; a pin is put through the end of the bolt to prevent it being drawn quite through at *e*; a circular plate of iron is pinned fast upon the bolt *b*, between which, and the fixed plate *d*, a spiral steel spring is placed, which has a strong tendency to elongate itself, and draw the hook to the machine: *h* is a short rack fastened to the iron plate *e*, and turning a small pinion on the back of the index *i*, which points out the divisions on the arc *k*. The divisions are made by suspending weights from the hook *a*; these compress the spring in proportion to their weight, and the rack moves the index *i*; the value of each weight being marked on the arc *k* at the place pointed out by the index:

of courſe, when the horſes are harneſſed to the whippletrees B, B, and the plough, or carriage, to the hook *a*, the motion of the index denotes the force of their draught.

Fig. 2. is another machine on the ſame principle as the laſt, but is contrived ſo as to require a very delicate ſpring, which is found to be more ſenſible than a large one, and to keep its elaſticity longer: this is accompliſhed by having the hook *a* formed into two eyes at the other end, to receive the pivots of the lever *b*, whoſe fulcrum, or fixed centre, is at *d*; at the other end of the lever it is connected by a ſhort iron link *e*, to a ſecond lever *f*, of which *g* is the fulcrum: *h* is the ſpring barrel, exactly the ſame as the other machine, but much ſmaller, being only to weigh about 50*lb.* inſtead of 5 *cwt.*; its ſpindle is attached to the lever *f*, and is moved thereby when the hook *a* is drawn: the ſpindle of the ſpring has a rack *i* faſtened to it, which moves a ſmall pinion, on whoſe arbor the index to the dial-plate is fixed: the dial plate is in this machine a whole circle, deſcribed in the figure by a dotted circle, with large diviſions for hundred weights, and ſubdiviſions for the quarters. By means of the levers the power exerted on the hook is ſo far diminiſhed, that the ſmall ſpring of 50*lb.* will ſerve to weigh a quantity equal to 6 *cwt.*; and by increaſing the ſpring a little, and altering the levers, by throwing the hooks nearer the centres, and lengthening the levers, it may be made to do for 12 *cwt.* The mechaniſm is covered over with an iron box, to defend it from injury.

This machine is the invention of Mr. Robert Salmon, Woburn, Bedfordſhire, and they are now manufactured by Mr. Shepherd, implement-maker, Woburn.

This article is alſo the moſt proper place to deſcribe a method, employed by Mr. Salmon, to meaſure the force requiſite to give motion to a threſhing and flour mill at Woburn-Park farm, belonging to the duke of Bedford. The mill was originally worked by a horſe-wheel, adapted for eight horſes or oxen, though it is now worked by a ſteam-engine; but the horſe-wheel ſtill remains. It is repreſented in *fig.* 3, where A A is the main vertical ſhaft, having pivots at both ends, one of which works in a braſs ſocket, ſupported on beams, *a*, *a*, laid on the ground; and the other in a braſs bearing, bolted to the *a* beam, which is framed between two girders, B, B, of the floor above. D is the rim of the wheel, containing the cogs; it is compoſed of three thickneſſes faſtened together, and is ſupported by ſixteen arms, F, from the enlarged part of the ſhaft at E, and braced by ſixteen beams, L, extending from the lower part of the ſhaft to the middle of the arms. The horſes or oxen draw from upright pieces of wood, *a*, *a*, bolted to the arms, F, and braced by long iron bars from the adjoining arms. Eight of the arms are furniſhed in this manner, for the oxen to work the wheel: they walk upon a circular road at G G, on the level of the ground, while the ſhaft is ſunk in a pit walled round, to give a greater length of ſhaft, that the oblique braces may have more effect.

The method in which Mr. Salmon applied a dynamometer to this wheel was as follows: a piece of board, *b*, was extended between and nailed to the two uprights, *a*, *a*, by which the oxen drew; in the middle of the board a large pulley, *g*, was fitted, turning very freely, and upon as ſmall a pivot as was conſiſtent with ſtrength; another pulley, *d*, was ſuſpended from the arm of the wheel near the centre; a ſmall ſoft rope was paſſed over both pulleys, hanging ſtraight down from the pulley, *d*, and terminating in a double hook, and after paſſing round the pulley, *g*, was tied to the middle of a ſhort round ſtick. Four of the arms were fitted up in this manner, and two men were placed at each, holding the ſtick in their hands behind them. Mr. Salmon placed himſelf in the pit, being provided with a number of weights, ſome of which he hooked on the hooks at the end of the rope. He then directed the men to proceed forwards, in the track formed by the feet of the cattle, drawing the rope after them. Their action raiſed the weights, and cauſed the wheel to follow; but where the weights were drawn up towards the pulley *d*, Mr. S. added more weight, until it was ſo adjuſted that the wheel moved round with its proper velocity, without the weights riſing or falling above any point at which they were placed. The ſum of theſe weights now ſhewed the power required to move the mill; and the motion might be continued as long as was neceſſary to obtain a fair reſult. By this method, any ſudden jerk or exertion, which the men might make, would not be communicated to the wheel, as it would only draw up the weights, which would deſcend again, when the men relaxed their ſtrain.

The mill was employed in threſhing; and as this is a very unequal kind of work, it was often neceſſary to hook on more weights, to overcome the reſiſtance occaſioned by feeding the machine: for it muſt be obſerved, that no more power could be applied to the wheel than the ſum of the weights, as it was only through the medium of horſes that the men exerted any power at all upon the wheel.

The velocity of the wheel alſo depended upon the weights, for the heavier they were the quicker it would follow the men, who were directed to move at ſuch a pace, as the wheel ſeemed to take, that the weights might not deſcend by their going too ſlow, or aſcend by their going too faſt. The wheel's velocity was meaſured by a watch which Mr. S. had in his hand; and each turn of the wheel was denoted to him, by a nail which was drove in the rim of the wheel ſtriking a piece of tin plate nailed up againſt the wall. If he found by the watch the wheel was moving too ſlowly, he applied more weight, or *vice verſâ*, until the proper weight was found. Mr. Salmon made many experiments in this manner, on the force required to thraſh different kinds of corn, of which we ſhall give the reſults under Threshing Mill.

Eliquation

ELIQUATION, or LIQUATION, in *Metallurgy*, is an ingenious procefs of feparating filver from copper by means of lead, which appears now, however, to be very little employed; but a fhort account of it may be here given.

When rough unrefined copper contains filver in the proportion proper for this operation, it is firft melted with a large quantity of lead, and the mixed alloy is caft into loaves or conical maffes. Thefe are then fet in a furnace on an inclined plane of iron, with a fmall channel grooved out and heated to a degree juft below that of the melting point of the alloy, during which the lead melts, or, as it were, fweats out of the loaf, carrying with it the filver, and the copper is left behind as a reddifh black fpongy mafs. This laft is properly the procefs of eliquation. The filver-holding lead is then purified on a cupel, in the way which will be defcribed under the article SILVER.

Eliquation can only be performed with certain proportions of the three metals concerned in the procefs. According to Cramer (Docimafia practica: proceffus 48), every half ounce of filver requires 17lbs. (or 544 times its weight) of lead for its extraction from copper by a fingle eliquation; and on the other hand, the lead fhould not be more than about four times the weight of the copper, otherwife the mafs will prove too fufible, and the whole loaf will melt down at the heat neceffary for the extraction of the lead and filver. On the other hand, if the lead is lefs than about $2\frac{1}{2}$ times the weight of the copper, the loaf of liquation will not yield all the lead in one procefs, and much of this metal, and along with it part of the filver, will remain after the operation.

The above data (allowing four times as much lead as copper) would therefore give for the due proportions of the alloy 544 parts of lead, 136 of copper, and one of filver. Other metallurgifts diminifh the lead fomewhat, making it to the copper only as 11 to 3.

The whole procefs of liquation is defcribed at length in a valuable paper by Duhamel, in the Memoires de l'Acad. for 1788, from which the following is a fhort extract.

The lead and crude filver-holding copper, being duly proportioned, are thrown into a high blaft furnace, the floor of which is lined with a mixture of clay and charcoal, rammed hard, and laid in an inclined direction, fo as to convey the melted metal into a feparate receptacle. The crude copper is firft broken in fmall pieces when hot, and affayed, to determine the proportion of filver. Either lead or litharge is ufed in the mixture; if the latter, it is mixed with charcoal to promote its reduction, and 120 parts of the litharge are taken as equivalent to 100 of lead. The furnace being firft heated by itfelf for fome hours, a bafket full of the fcoriæ from the firft reduction of the copper ore is thrown in, which foon melts, and forms a vitreous glazing, that protects the walls of the furnace from the violent action of the blaft. The mixed metals are then thrown in at intervals, and the whole foon melts into a triple alloy, which flows into the receptacle, whence it is tapped out into iron moulds, whereby it affumes the conical fhape requifite for the fubfequent eliquation. The heat required in this firft operation is much lefs than that at which copper melts, fo that the fufion and reduction of the litharge go on fpeedily, and in a well-managed furnace, feven loaves of liquation, each weighing about 350lbs., may be caft in an hour.

The next procefs is the *eliquation*, which is performed in a furnace conftructed for the purpofe, ufually holding fix loaves, fet on iron bars, feparated from each other by bricks, and having a channel beneath to convey the filver-holding lead into a bafon as it melts out. The management of the heat is here of great importance. If the procefs goes on well, the lead flows out eafily, and the loaves gradually fink down, and become honey-combed, without lofing any fenfible portion of their copper. If the heat is too great, particles of copper are vifibly carried down with the lead, which muft be immediately prevented by flackening the fire. When the lead has ceafed to flow, the loaves are taken out, and when cold have a dark red colour and a crumbly texture. It requires about four hours to eliquiate the loaves. The firft portion of the lead is always the richeft in filver, but whatever care is taken in the procefs a little of both filver and lead remains, together with part of the iron, arfenic, and other impurities of the copper.

To collect the fmall remaining portion of filver, a number of the porous loaves remaining after liquation are ranged in a kind of oven fo as nearly to fill it, and are made moderately red-hot by the flame of wood drawing through it, by which a quantity of mixed metal and fcoriæ drops down on the hearth, confifting of lead holding a little filver, of iron, fulphur, arfenic, fome copper, and fcoriæ. This mafs is wafhed in a ftamping machine, by which the fcoriæ are got rid of, and the metals alone remain, which undergo a further purification. When the dropping from the oven-furnace begins to be red and compact, it is a fign that all that is heterogeneous to the copper, which can be extracted in this way, is got out, and the copper itfelf begins to melt. The loaves are then taken out, and appear varnifhed with a thick vitrefcent mafs, which, on dropping them into cold water, cracks in every direction, and when cold, may be knocked off with a hammer, leaving the copper confiderably pure. This procefs lafts about 30 hours.

The filver, now transferred to the lead, is afterwards refined in the ufual manner.

The procefs of eliquation, though highly ingenious, is expenfive and difficult to conduct, and requires a large fupply of lead. To perform it economically, it alfo requires a copper holding a pretty exact proportion of filver, that is, from $\frac{2}{3}$ds to $\frac{3}{4}$ths per cent. of filver, neither more nor lefs, and hence, where there are parcels of copper of greater or lefs richnefs in filver, much judgment is exercifed in mixing them in fuch proportions as to allow of eliquation with the leaft expence.

Enamelling

ENAMELLING. The art of enamelling is of great antiquity, but of unknown origin. That it was practifed by the Egyptians is evident, from the remains that have been obferved on the ornamental envelopes of mummies. From them it probably paffed to the Greeks, and afterwards to the Romans, who appear to have introduced the art into this country; as various Roman antiquities have been dug up in different parts of Britain, in which enamels have formed portions of the ornaments. That the Britons received the art from their conquerors may be conjectured from the circumftance of enamelled trinkets having been found in Britifh barrows. That the Saxons practifed it is certain, from the jewel found at Athelney in Somerfetfhire, and now preferved at Oxford; which jewel, as appears by the infcription, was made by command of the great Alfred. The gold cup, given by king John to the corporation of Lynn in Norfolk, proves that the art was not loft under the Normans; for the fides of that cup are embellifhed with various figures, whofe garments are partly compofed of coloured enamels. The tomb of Edward the Confeffor in Weftminfter Abbey, conftructed in the reign of Henry III., was alfo ornamented with enamels, pieces of which ftill remain. The beautiful crozier of the celebrated William of Wykeham, of the time of Edward III., may be alfo adduced as exhibiting fome curious fpecimens of the application of this art: and other examples might be pointed out, of its progreffive defcent to our own age.

It would feem from the above brief review, that anciently enamels were principally applied to the purpofes of ornament; but fince the invention of clocks and watches, their ufefulnefs has been proportionally increafed. For clock and watch dials there is probably no fubftance that could be fubftituted, that can equal enamel in permanence and beauty: in feveral refpects, it poffeffes advantages even over the rich metals of filver and gold. Within the laft 30 or 40 years, an *imitative enamel* has been ufed, and, through the fcarcity of real enamel, is now in much demand for clock plates; but it is by no means comparable with its prototype: for, being chiefly compofed of flake white, ground up with fpirits of turpentine, and afterwards mixed with copal varnifh, it will neither affume an equal brilliancy in colour, nor continue unchanged in different climates; on the contrary, the action of the air occafions it to become dingy and yellow. In fact, imitative enamelling is nothing more than a branch of the art of *japanning*; which fee.

The proceffes of enamelling have never been accurately defcribed. The jealoufies that exift in all arts in which any thing like a fcientific knowledge is wanting, operate to feclufion. The practitioner conceals his information from motives of profit, and the amateur feldom acquires an infight fufficiently minute to enable him to unfold the modes of operation. Whatever may be the defects of the prefent attempt, it will be found to contain a better account of the practical branches of the art than has before appeared.

Enamels are commonly laid upon a metal ground, yet they have been fometimes ufed in fubftance, for difhes, flower-pots, ornamental veffels, figures, vafes, &c. In thefe cafes, the enamel is run into moulds immediately from the pots in which it has been melted. The metals employed to enamel on are gold, filver, and copper. Of the other metals, fome are too fufible to endure the action of the fire, and the remainder, as platina, &c. are, to ufe the language of the art, too *ftrong*, for the enamel: that is, the adhefion between the two fubftances is not powerful enough to keep them together, the enamel cracking as it grows cold, and flying off the metal in flakes. It appears, therefore, that a certain, however flight, degree of oxydation is neceffary to make the enamel and the metal unite with fufficient firmnefs. Gold is unqueftionably the beft fubftance to enamel on, its richnefs of colour fhowing a beautiful tinge through the enamel: yet the metal generally ufed, except for watch-cafes, and valuable articles of jewellery, is copper; and that on account of its fuperior cheapnefs. Both the gold and the copper fhould be of the finer kinds, the others being too refractory to agree properly with the enamel.

By the cuftom of the trade, rather than from any principle of utility, enamelling is now divided into two branches, *viz.* dial-plate enamelling, and tranfparent enamelling. The former includes the manufacture of clock and watch plates, with fluxed plates for enamel painting, the latter comprehends the enamelling of watch cafes, broaches, pins, and other bijoux: of late years the making of thefe leffer articles has gradually grown into great difufe in this country.

Dial-Plate Enamelling, confifts of the two divifions of hard-enamelling, and foft, or glafs enamelling; in the firft branch, the Venetian enamels only are employed, in the laft, the Englifh or glafs enamels. The practice of hard-enamelling requires more fkill, time, and labour than the others, and is confequently efteemed the moft. In preparing the metals to be enamelled on, whether of gold, filver, or copper, the procefs is fimilar; one defcription will therefore fuffice for the whole:—and firft of the making of watch dials.

The copper being evenly flatted in long flips (which is done at the flatting mills between fteel rollers) and to a proper thicknefs, pieces are cut off for ufe according to the fize wanted. They are then annealed in a clear fire, in order to make them fufficiently pliable to take the required forms which is given to them by means of dies. The dies are fmall circular plates of brafs evenly turned, varying in thicknefs, perhaps, from the fixteenth of an inch to an eighth, or more, according to their diameter. Some of them are flat, others are hollowed out for the purpofe of giving a flight curve to the *copper*, as the metal to be enamelled on is technically termed when prepared for ufe: the edges of the dies are turned off in an oblique direction, and in the centre is a fmall hole, rather larger than that which is wanted in the dial-plate. A complete fet of dies varies in fize from about three-fourths of an inch to two inches and a half, the gradations being very fmall, perhaps

not more than the thirty-fecond part of an inch between each.

The copper being cut with a pair of fciffars nearly to the fize required and properly annealed, is next placed on the die beft adapted for the purpofe, and the eye, or centre hole, is made. This is effected by firft forcing up the copper into the hole of the die with a fmall round-headed punch; by this means a fmall concave bulge is formed, the upper fide of which is then filed through with a fmooth grained file; it is then again placed on the die, and preffed gradually open till it nearly fills the hole with an oval burnifher; it is afterwards preffed tighter into the hole with a round broach, the burr being occafionally taken off by the file, and care employed to prevent the eye from cracking. The punch, burnifher, and round pin, are all of fteel; the two latter taper in regular gradation towards the handles.

When the eye is completed, the edge of the copper is cut round, fo as to leave a fmall part, probably about the thirtieth of an inch, projecting beyond the die. The projecting part is then turned up, or burnifhed, againft the edge of the die, the copper being firft laid fmooth and flat by the burnifher. The turned-up edge of the copper is afterwards filed evenly round, and reduced to the proper height, according to the thicknefs of the brafs-edge, or rim, to which it is to be fixed when in the watch. The infide burr is then fcraped off with a graver, and ftill further cleared away by means of a fcratch-brufh: this latter tool is compofed of fmall brafs or fteel wire tied together in a round bundle, about the fize of the little finger. The purpofe for which the eye of the copper is formed, and the edge turned up, is to retain the enamel in its proper place, fo that the plate may be finifhed both fquare and neat.

According to the kind of watch to which the dial is to be applied, the copper, if for a feconds watch, muft be kept almoft flat; or if for a watch where a greater fpace is wanting beneath, to give more fcope for the wheels, muft be raifed from the edge to the centre in a regular and exact manner. To effect this a fmall circular block or fetting die is ufed, made of box or other hard wood turned out to the neceffary degree of concavity, and having a hole in the middle to receive the eye of the copper when placed within the hollow of the block. The copper is then gradually fet up to the convexity or height required by rubbing it gently yet firmly with a bent, or fetting fpatula, formed of a thin flip of fteel, about five inches long, properly fixed. It is now ready to have the feet foldered on, by which it is to be pinned down to the brafs edge or frame of the watch; and the places for the feet being marked on the back of the copper, through the holes drilled for the purpofe in the edge or frame, the feet are prepared for foldering.

The feet are alwaysof wire of the fame kind of metal as that to be enamelled on, and the wire is drawn into different thickneffes, proportioned to the fize of the intended dial-plate; thus varying perhaps from the tenth to the fixteenth of an inch. In the more common kinds of enamelling, the feet are generally cut off from filvered wire, that is, copper wire plated with filver; the filver itfelf forming the folder when the feet and copper are expofed to the united action of the lamp and blow-pipe. In the beft kind of work plain copper wire is ufed, and the feet are faftened to the copper by means of fpeltre, or of filver folder. When fufficient care is exercifed, either of thefe modes is equally appropriate, but the feet foldered on with fpeltre take the firmeft hold; thofe with the filvered wire the flighteft. The feet are evenly filed, either to a flat face, or an angular one, according to the defcription of copper for which they are wanted; and are cut off the wire into proper lengths by a pair of cutting-pliers or nippers. In order to make the feet remain in their places, and facilitate the foldering, the end of each foot, before putting it on the copper (which is done by means of a pair of corn-tongs or tweezers), is dipped into a flight wafh of borax and water, through which it adheres with fufficient force to admit of its being expofed to the power of the blow-pipe. The lamp in common ufe contains from a pint to a quart of oil, and has a cylindrical fpout projecting about three inches, and being an inch or more in diameter. This fpace is filled with cotton, which being lighted, a good ftrong flame is produced. The copper is carefully placed upon a piece of folid charcoal, long enough to be held in the hand, and the flame being then propelled by the blow-pipe againft the folder, or filvered wire, as the cafe may be, the feet are firmly united to the copper. In this operation, attention muft be given to the exact degree of heat required to fufe the folder, for fhould it be too powerful, the copper itfelf will melt at the fame inftant: care muft be taken alfo that all the feet keep in their due places, otherwife the copper will not fit properly, and the feet muft either be cut off, and new ones foldered on, or much trouble will be found in drawing the holes of the brafs-edges or frames, to get the coppers into their proper centrical fituations.

The copper being thus far advanced is thrown into the pickling-pan, in order to free it from the fcale or oxydable covering acquired from the heat. The *pickle* is either oil of vitriol, fufficiently neutralized for the purpofe by water, or elfe a folution of the beft double aquafortis. When the fcale is enough foftened to admit of its being removed by a foft brufh, ufed with water and a little white fand, the copper is taken out of the pickle, and all the impurities being wafhed away, it is dried by means of heat, or elfe with a foft cloth. In this ftate, the copper will generally require to be again put into a proper fhape, by means of the brafs die, and fetting block, as it is fcarcely poffible but that fome irregularities will be produced through the operations laft defcribed. It is alfo hardened in a flight degree by rubbing the under fide with the fetting fpatula, and the furface with the fcratch brufh. When this is done, the copper is completed, and fit to be enamelled on. It is to be remarked, that when many coppers are prepared at once, much time is faved by turning off the edges by means of the lathe and arbour, inftead of by filing them even in the manner detailed above.

The above are the methods by which the common coppers are prepared; it is now requifite to defcribe what are called *French edges*, from their having been firft made in France. Thefe are of two kinds, the folid French edge and the laid-down French edge. To make the former, a piece of copper is taken, either about a fixteenth or a twelfth of an inch thick, according to the diameter of the intended plate, and a hole being drilled in the centre, the copper is placed upon an arbour, and fixed tightly by means of a fmall cone and fcrew-nut fitted to the maundrel. The arbour being then fixed upon a lathe, the edge of the copper is next turned off in an oblique direction, inclining inwards, with a graver, and the copper is then reduced to the proper thicknefs for enamelling from the edge to the centre, by means of a fcorper and other tools; thus leaving the edge folid, and taking care alfo that a fufficient fubftance is left unreduced round the cone, to form the outer circle of the eye. The laid-down French edge is made by preparing a copper in the common way from a thin flip, the edge being left rather higher than ufual, and then fixing it upon the arbour, when the edge of the copper being firft turned perfectly even with a

graver, is next forcibly bent inwards by a ſmall triangular tool, (perhaps formed from the end of a three-ſquare file worn ſmooth,) and afterwards ſquared and finiſhed by the graver and ſcratch-bruſh. It is in general neceſſary to reverſe the coppers on the arbour, and turn a ſmall portion of the under ſide away, both of the ſolid and laid-down kinds, in order to make the edge of a due ſharpneſs. The coppers are laſtly ſet up, and the feet ſoldered on, as before deſcribed. French edges are moſtly uſed for watches of a particular kind, where room is wanting, and the dials are fixed upon the frames without a braſs-edge.

When a dial is made for a ſeconds' watch, or for one requiring ſtill more circles than two, the additional eye, or eyes, is made by marking the centres accurately with a point on the under ſide of the copper, and then bulging the copper upwards with a ſmall punch from each centre, by ſtriking it gently with a ſmall hammer into a piece of lead, about three times the thickneſs of a die; the lead forms a ſufficient reſiſtance to prevent the eye from cracking, and is yet ſoft enough to admit of the copper being bulged up evenly. The ſmall eyes are afterwards evened with the file, and opened with a ſmall needle or round-pin to the required ſizes. Some trivial variations in the mode of making the ſeconds' holes, &c. occaſionally occur.

The coppers being thus prepared, the next proceſs is that of *enamelling*, properly ſo called. Where the operations of *hard* enamelling, and *glaſs* enamelling, are diſſimilar, the difference will be deſcribed in proceeding, but to a certain extent they are the ſame.

The enamel, as it comes from the makers, is generally in ſmall cakes from four to five or ſix inches in diameter. In preparing it for uſe, a ſmall hammer is uſed, having one end flat, and the other of the ſhape commonly employed to rivet with. With this the enamel is broken into thin pieces or flakes, by ſtriking the edge of the cake ſmartly as it reſts upon the fore finger of the left-hand. The pieces are then put into an agate mortar, and with a peſtle of the ſame kind are finely pulverized, the ſplinters being prevented from flying about, by keeping the enamel covered with pure water all the time the proceſs of *grinding* is going on. The point at which the trituration ſhould be diſcontinued, can only be aſcertained from experience, as the different kinds of enamel, and the different modes of its application, require the *ground* enamel to be either more or leſs fine. In general it may be ſtated, that the *backing* ſhould be much finer than the *firſt coat;* the *ſecond coat* of an intermediate fineneſs; the hard enamels conſiderably finer than the glaſs, and the flux ſtill finer than thoſe, as the fire operates with leſs effect upon the flux than upon either of the former ſubſtances. In grinding, great care muſt be taken to keep the enamel free from dirt, and the light flue which ariſes muſt be waſhed away three, four, or more times, as may be neceſſary in the courſe of the operation, till the water comes off quite clear. A ſmall tea-pot is commonly uſed to pour the water from, and when the enamel is ground ſufficiently, the produce is emptied into ſome other ſmall cup for uſe, the ſurface being kept juſt covered with water.

The manner in which the grinding is performed, is by placing the mortar upon the work-board, on a coarſe piece of flannel or linen, twice or thrice doubled, and wetted to prevent its ſlipping. The handle of the peſtle is then graſped firmly about the middle with one hand, and the palm of the other being placed upon the top, the operator inclines the upper part of his body over the mortar, and cruſhes the enamel by preſſing forcibly with his breaſt upon that hand which covers the peſtle. This motion is repeated in quick ſucceſſion, till all the larger pieces are reduced into coarſe and uneven grains; which grains are afterwards groun to the requiſite equality and fineneſs, by holding the mortar firmly down with one hand, and with the other giving a circular direction to the peſtle, uſing at the ſame time as much ſtrength as can be conveniently exerted.

In enamelling watch dials, many coppers are uſually prepared to go on with at once; that method poſſeſſing the three-fold advantage of ſaving time, materials, and labour. When the enamel is ground, therefore, the coppers having been firſt cleaned by the pickle, and carefully bruſhed out with water, are ſpread, face downwards, over a ſoft half-worn cloth, or ſmooth napkin, and a thin layer of hard enamel, called, in its ground ſtate, the *backing*, is ſpread over the under ſides with the end of a quill, properly cut, or with a ſmall bone ſpoon. The coppers are then ſlightly preſſed on by another ſoft cloth or napkin, which, by imbibing ſome portion of the water, renders the enamel ſufficiently dry to be ſmoothly and evenly ſpread with the rounded ſide of a ſteel ſpatula. The water is then again dried out by the napkin, and a yet further evenneſs produced by going over the enamel as before, with the ſpatula, and theſe operations are repeated, till the back becomes completely ſmooth, and the enamel is of an equal thickneſs all over. It muſt be obſerved, that the water ſhould not be *entirely* abſorbed, as in that caſe the enamel would fall off, in powder, before the ſubſequent operations are completed. When the enamel is properly ſpread, the looſe particles are carefully cleared away from the edge and eye of the coppers; from the former by the ſpatula, from the latter by twiſting round it the pointed end of a quill, and the proceſs of *laying the bottoms* is thus finiſhed. Some ſlight variations to the above method are in uſe among different artiſts, but the difference is ſcarcely important enough to require deſcription. In ſome inſtances the enamel is laid on with the ſpatula itſelf, and the coppers, inſtead of being held between the fingers, are placed upon the round pin, by means of the centre holes, till the backs are duly ſpread: in both modes due care muſt be taken that the coppers are not bent out of their proper forms.

The next operation is to lay the *firſt coats;* that is, to ſpread a layer of *glaſs* enamel over the upper ſides of the coppers. In doing this, the ſurface is firſt bruſhed ſlightly over with a ſmall camel-hair bruſh, or a hare's foot, to remove any dirt or extraneous particles of enamel, as the mixture of any hard enamel with the glaſs would infallibly ſpoil the work. The glaſs is then ſpread upon the coppers in a layer, the thickneſs of which is commonly the ſame as the height of the edge and eye. The water is afterwards ſlightly abſorbed with a clean napkin ſmoothly folded, and the enamel ſpread by a thin, flat ſpatula, till all unevenneſs is removed, and the ſurface lies regularly from edge to centre. The edge being then gently tapped twice or thrice at different places with the ſpatula, the water riſes towards the top, and is again dried off by the napkin, when the enamel is once more made ſmooth by the ſpatula, and the water being wholly taken up by the napkin, or as nearly ſo as can be effected, without diſturbing the enamel, the *firſt coats* are placed upon rings for *firing*.

The rings uſed in enamelling are generally made of a mixture of pipe-maker's clay and Stourbridge clay, rolled up into the form of cylinders, and turned in a lathe by means of a cylindrical piece of wood forced through the centre of the maſs when wet. Each ring is about a quarter of an inch in thickneſs, and the ſame in depth; the upper ſide is prepared for uſe by rendering it ſlightly concave, which is done by rubbing it carefully upon a half globe of lead ſprinkled over with fine ſilver ſand: the under ſide is nearly flat. Through the concavity thus given to the rings,

the edge of the copper or dial-plate only is ſuffered to touch, by which means the enamel on the back remains undiſturbed, and the edges are prevented from ſticking by rubbing over the ſurfaces of the rings with ſoft chalk or whiting.

The firſt coats having been placed carefully upon the rings, are next put into a ſhallow tin veſſel, called a tin cover, which is either made ſquare or round, according to the fancy of the artificer, and is commonly about three quarters of an inch in depth. All the moiſture is then ſlowly evaporated from the enamel, by placing the cover upon a German ſtove, or in ſome other convenient ſituation near a fire, where the evaporation can be properly regulated: for, ſhould the water be dried off too quickly, the work would be in danger of ſpoiling from *blebs* or *bliſters*. Theſe are very ſmall air-bubbles, which, by riſing to the ſurface of the dial-plates, deſtroy their ſmoothneſs and beauty. They appear to be occaſioned, partly by want of due care in laying on the enamel, and partly by the confinement of the air which the water contained, and which, in the proceſs of firing, becomes rarefied; throwing off, by its expanſion, a portion of the ſurrounding enamel, yet not entirely eſcaping without a very vivid heat, and even then reſolving into black or green ſpecks, ſo coloured through the oxydation of the copper.

The *firing* is executed beneath a muffle, placed in a ſmall furnace ignited with coke and charcoal. (See Muffle and Furnace *Enamellers*.) The furnace being drawn up to a ſufficient heat by means of a regiſter, the firſt coats are taken ſeparately from the tin covers, and placed upon thin planches of clay, or iron, chalked over, and gradually introduced beneath the muffle; where, in a very ſhort time, the enamel melts, or technically *runs*; and becoming properly conſolidated, the firſt coat is complete. Great attention is requiſite in this operation, to prevent the enamel from being over-fired; as in that caſe, the glaſs would loſe ſome portion of its opacity, and other defects alſo be produced, to the detriment of the work. The planches are placed towards the further extremity of the muffle, by means of a pair of ſpring tongs; and as ſoon as the fuſion is ſeen to take place, are turned carefully round, in order that every part ſhould be equally fired. The planches are generally made circular, and ſlightly concave, for the convenience of moving the work without danger of ſhaking off the enamel before it becomes fixed by the heat.

As all ſolids, when reduced to a granulated ſtate, occupy a greater ſpace than before, *et vice verſâ*, it will be found that a very conſiderable depreſſion has been produced in the enamel of the firſt coats by the act of fuſion; and that the edge and eye are now much above the ſurface. This deficiency in ſubſtance it is the office of the *ſecond coats* to ſupply. When the work is cooled, therefore, the ſcale is wholly removed from the edges and eyes by means of a fine-grained Lancaſhire file, or a ſmooth grey-ſtone; and being then waſhed and dried, each plate is put upon a ſmall round wax-block, of ſufficient bulk to be held in the hand, and about four or five inches high. The feet are then either preſſed firmly into the wax which covers one end of the block, or the plate is otherwiſe fixed by means of three ſmall cones of wax placed triangular-wiſe upon the block; care being taken not to ſtrain the enamel by too weighty a preſſure. A ſecond layer of ground enamel is then gently ſpread with a quill, and prepared for firing by the napkin and ſpatula as before; after which the ſecond coats are placed upon the rings, and the moiſture being evaporated in the tin-cover, (one edge of which, both in this and in the preceding operation, ſhould be left a little open to give iſſue to the ſteam,) they are ready for a ſecond fire.

The ſecond firing requires an equally cautious management as the former one. The plates muſt not be over-fired, nor muſt the heat be ſuffered to melt the enamel too rapidly; but a kind of rotatory motion, called *coddling*, muſt be given to the work, by holding the loaded planch lightly with the tongs, and gently drawing the edge of it towards the mouth of the muffle, and then returning it to its former place, till the fuſion be complete; a proper knowledge of which can be gained only from practice. The work is now in a fit ſtate for poliſhing.

Poliſhing, in this art, has a twofold ſignification: it not only means to render bright, according to the common acceptation of the term; but alſo to make even, without any reference to gloſſyneſs. The enamel has a natural brightneſs of ſurface acquired from the fire; and when this is removed, it is only neceſſary again to expoſe it to a due heat, to cauſe it to reaſſume its former character. Yet as this brightneſs exiſts independent of evenneſs, and as evenneſs is eſſential to the perfection of enamelling, it is requiſite, in moſt caſes, to produce that quality by the methods next to be deſcribed.

The materials uſed in poliſhing glaſs plates are grey-ſtones, rag-ſtones, ſometimes called burrs, fine ground ſilver ſand, and water. The grey-ſtones ought to be of a fine grain and even texture, without knots, which would be very detrimental by making deep ſcratches in the enamel, inſtead of wearing it away evenly. The plates are taken ſeparately, and the thin edges are firſt worn off by one of the finer grey-ſtones, till they become ſmooth and equal; after which the eyes are rubbed down, till the centre of each plate is even and ſquare. Either the grey-ſtone or the rag-ſtone is next employed, according to the nature of the work, to wear away all the irregularities that may exiſt on the ſurface of the enamel; the rag-ſtones being only uſed for the more common kinds of dials. This is done in different ways; *viz*. firſt, either by holding the plate upon the fore and middle finger of one hand, and giving it a ſort of circular motion by means of the thumb, whilſt with the other hand the poliſhing-ſtone is rubbed with a forward and backward ſtroke over every part of the ſurface; ſecondly, by holding the poliſhing-ſtone on the work-board with one hand, and with the other rubbing upon it the face of the enamel; or, thirdly, by fixing the plate upon a cork, either by means of the feet, or with a piece of wet flannel, and with the fingers giving it a kind of rotatory motion, whilſt the poliſhing-ſtone is rubbed over it in a ſimilar manner. The ground ſilver ſand is uſed to give ſharpneſs to the poliſhing-ſtones, and wear away the enamel with greater celerity than would be otherwiſe acquired; and the act of poliſhing is continued till all the gloſs is ground off the ſurface. In this operation great care muſt be taken that the preſſure be not too powerful, as the plates will then crack in the fire, and can never, or very rarely, be properly mended.

When the enamel is ſufficiently poliſhed, which is eaſily known by the criterion of all the gloſs being removed, the plates muſt be clean waſhed, and the ſpecks of dirt, &c. picked out with a ſharp graver. They are then well rubbed over with ſome fine ground glaſs, either by means of a cloth, a glaſs mull, or perhaps a ſmall bit of fir-wood cut ſmooth, in order to remove the ſtains that may be left by the poliſhing-ſtones; and the clean water being ſuffered to run over them, they are wiped dry, and again placed upon the rings for firing.

The degree of heat neceſſary for poliſhed plates is determined by the finer or coarſer modes in which they were prepared; as the fuſion is much facilitated by the enamel being free from ſcratches. When the ſurface is properly run, that is, when it becomes perfectly ſmooth, even, and bright, the plate is completed; and when cold, is fit for painting on. See PAINTING of *Clock and Watch Dial-Plates*.

The above deſcription regards more particularly the beſt kinds of work; but for the more common work there are two other modes of enamelling practiſed, which it will be requiſite briefly to explain. The plates made in theſe ways are called *run-down plates*, and *run-down ſecond coats*.

Run-down plates are thoſe which are made by laying the enamel upon the coppers in ſufficient quantity to form plates of the required thickneſs, without putting on a ſecond coat. Both labour and fire are thus ſaved; but that neatneſs, regularity, and ſquareneſs, which are acquired by the firſt method, are rarely obtainable in this: and indeed flat plates can hardly be managed at all in this mode. Run-down plates require more coddling than any other; and a longer continuance of vivid heat is neceſſary to make the glaſs flow to a proper evenneſs of ſurface: the plates being wholly completed with one fire, and without poliſhing. It is obvious that the moſt common work only can be thus manufactured; for that of the next ſuperior deſcription, the run-down *one coats*, are poliſhed off with the rag-ſtone, and undergo a ſecond firing. The run-down ſecond coats are thoſe which are reduced to a ſurface comparatively even by the ſecond fire, and are then painted on without being poliſhed off.

In enamelling *hard-plates* for watches, the coppers and the firſt coats are prepared in the manner above deſcribed; excepting perhaps that the layer of glaſs is rather thinner than in glaſs-work only. The hard enamel, which is generally moſt valued as it approaches to a rich cream colour, is broken down, and ground in the ſame way as the glaſs, if a ſmall quantity alone be wanted; but if otherwiſe, it is firſt broken from the cake with the hammer, and then pounded in a ſteel mortar, till reduced into coarſe grains. Theſe grains are then expoſed to the action of a magnet, in order that all the particles of ſteel that have been broken off the mortar in the act of pounding may be taken away, as they would infallibly ſpoil the work, by riſing in black ſpecks to the ſurface of the enamel, when in the fire. As an additional precaution, alſo, it is neceſſary to put the granulated enamel into a ſmall baſon, and pouring upon it a ſtrong ſolution of oil of vitriol, or aquafortis, to ſuffer it to ſtand for ſome hours, that the ſteel particles, &c. may be wholly diſſolved; after which, the enamel muſt be very carefully waſhed, till the water comes off pure and taſteleſs: for ſhould any of the acid remain, the work would certainly bliſter. The enamel is then ground to the neceſſary fineneſs in an agate mortar, and afterwards ſpread over the firſt coat with a quill, in ſmall quantities, and as evenly as it can be laid, that it may require the uſe of the ſpatula as little as poſſible. The water is then partly abſorbed by a very fine and clean napkin, and the enamel ſmoothly ſpread and cloſely compreſſed with the ſpatula; after which, more water is abſorbed, and the ſpreading is continued till the ſurface lies true and equal. The plate is then put upon a ring, and properly fired; and is afterwards poliſhed by placing it upon a cork, (the top edge being firſt taken off with a fine grey-ſtone,) and wearing away the ſurface, firſt, by a very fine-grained Lancaſhire file, or ſmooth piece of ſteel, and ſilver ſand, ground to an almoſt impalpable powder; ſecondly, by a fine blue-ſtone and ſand; and thirdly, by the blue-ſtone alone. With the latter a ſort of half-poliſh ſhould be given to the enamel; and the nigher that poliſh approaches to complete gloſſyneſs, the better; as the plate will then be finiſhed in the third fire with a leſs degree of heat than would be otherwiſe wanted. In this proceſs, much caution is required to prevent ſcratches, which cannot be *run up* by the fire without giving the enamel a greater heat than it will well bear. When the poliſhing is completed, the plate is carefully cleaned with ground enamel; and ſhould there be any ſpecks, they muſt be picked out with a ſmall and ſharp diamond, and the hollows very dextrouſly filled up with enamel from a quill-point, that they may neither riſe above or ſink below the common ſurface, when the plate is again fired: ſhould they actually do ſo, they muſt be made ſmooth with a blue-ſtone, and the plate muſt undergo a fourth fire, to render the ſurface of one uniform texture and gloſſyneſs. Hard-enamel dials are always conſiderably dearer than glaſs ones, through the greater labour, attention, &c. that are requiſite in making them; and the beſt watches are almoſt always made up with dials of this kind.

In the poliſhing off both of glaſs and hard plates, much addreſs is neceſſary to prevent a ſeparation between the enamel and the edge of the copper; for if too great a preſſure is exerciſed, or if the grey-ſtones, which are employed to wear down the copper, are of too rough a grit, the adheſion will be deſtroyed, and various black indents ariſe round the edge of the enamel, when the plate is again expoſed to the fire. In glaſs dials, theſe defects may be ſometimes amended; but in hard-enamel dials, ſcarcely ever.

The operations of *tranſparent enamelling* are nearly ſimilar to what have been already deſcribed in the making of watch dials. As the work is generally of a more minute kind, greater delicacy of handling perhaps is required; and as the enamels are of various colours and deſcriptions, more cups, veſſels, &c. and additional ſoft cloths or napkins, are wanting to keep them from mixing. Watch caſes are commonly enamelled upon gold, as well as moſt ſuperior articles of the fancy kind; and the ſurface of the gold is frequently engraved into different figures and compartments, before the enamel is laid on; by which means the work aſſumes a beautiful variegated appearance through the vitreous coating.

In enamelling the backs and edges of watch-caſes, &c. quince-water is frequently uſed as the medium by which the enamels are laid on; for this poſſeſſing a more adheſive and retentive quality than common water, better prevents the enamel from flowing from its proper ſituations: for where the convexity is conſiderable, the enamel will of courſe have a tendency to float towards the loweſt part. When enamels of different colours are intended to be employed on the ſame article, which is frequently the caſe in ornamental works, ſmall edges or prominent lines are left in the ſubſtance of the metal, for the purpoſe of keeping the enamels ſeparate; and theſe are poliſhed with the enamel, and reduced with it to a ſimilar equality of ſurface. Tranſparent enamels are not unfrequently poliſhed to complete gloſſyneſs, without expoſing them to an additional fire: in theſe caſes, the work is finiſhed with rotten-ſtone.

It is ſometimes deſirable to take off the enamel from a watch-caſe or trinket, without injuring the metallic part. For this purpoſe it has been recommended to lay a mixture of common ſalt, nitre, and alum in powder, upon the enamel requiring to be removed; and afterwards to put it into the furnace: and when the fuſion has commenced, to

throw the case, &c. suddenly into water, which causes the enamel to fly off in flakes.

In ornamental transparent work, a very pretty effect is often produced by applying small and very thin pieces of gold or silver, cut or stamped, into different figures, as acorns, oak-leaves, vine-leaves, bunches of grapes, fruits, &c. upon the surface of the first coating of enamel, where they are fixed by the fire; and are afterwards covered over by the second layer, through which they appear with considerable beauty. When any quantity of fancy-works of similar design is wanting, this mode of enamelling is much cheaper to execute than to have the surface of the metal itself engraved into the required forms.

Clock Dial-Plate Enamelling, is far more laborious than the other branches, and requires considerable experience to be properly executed, though the methods of operation are soon explained. The copper, being procured from the flatting mills in thin slips, and of an adequate diameter and thickness, is cut to nearly the required size with a pair of strong scissars, a circle having been first struck with the compasses. If in a soft state, it is then cleaned by the pickle, and having been brushed out with sand on a flat board, is washed and dried for planishing; if otherwise it must be well annealed before it is thrown into the pickle, where it must lie till all the scale is enough softened to be removed by the hand-brush, sand, and water.

Planishing is a very important part of clock-plate enamelling, and too much care cannot be exerted in the process, as the necessary regularity of surface almost wholly depends upon it. In large plates the action of the fire has a very considerable effect, as it causes an expansion in the metal, which, unless properly guarded against, cannot but operate to the imperfection, and perhaps total spoiling of the work. In flatting also, a sort of twist is not unfrequently given to the copper, during its passage through the rollers, that would assuredly cause the plate to become uneven and out of shape, were it not to be removed by planishing and repeated annealings. Another effect produced by the fire, is occasioning the plate to rise, perhaps irregularly, towards the centre, and this can only be checked by counteracting the action which the heat would otherwise generate in the metal by good planishing. To keep a large plate entirely flat is impossible; or at least no means have as yet been discovered through which that aim can be attained. The best way, therefore, to provide against the irregularities which the fire might cause, is to give to the copper, in the course of planishing, a slight and even rise or curve from the edge to the centre; this can either be effected by the use of large brass dies, or by a machine adapted for the purpose.

The *machine* of which, probably, there is only one in the trade, consists of two principal parts; the one a solid mass of iron, with a concave and polished face, imbedded immoveably in a strong oak block, firmly fixed on a foundation of brick-work, and the top edge hooped with a thick iron ring, to prevent splitting; the other, an answering and weighty mass of iron with a convex face, similarly polished, and fixed in an upright frame of timber, but so contrived as to become *moveable* by means of sliding grooves, a rope, a pulley, and a lever, and so placed as to fall directly upon the mass beneath, in a similar way to the monkey of a pile-driving engine. The diameter both of the hammer and the anvil, as the upper and under masses of iron may be called, for the sake of perspicuity, is about thirteen inches; that size being nearly as large as clock dials are ever made or wanted. The convexity of the hammer is exactly fitted to the concavity of the anvil, and may be described, perhaps, as forming a portion of a circle fifty feet in diameter; and the centres of both are kept true to each other, and conse-quently to the regularity of curve, by means of large screws and nuts, which adjust the position of the hammer by altering the perpendicularity of the bars of iron that the grooves act upon. The power of this machine saves much labour in planishing, as well as time; yet as it is insufficient wholly to prepare the coppers, and as the charge of erecting one would be very considerable, it will never, perhaps, come into general use.

In planishing with this machine, it is necessary to be provided with various thin circular pieces of lead, evenly flatted, and adapted in size to the diameters of the coppers to be planished. Without these the stroke given by the hammer would have a very imperfect effect; and the impulse given by the weight of its fall would also be continually weakening the foundation and bed of the anvil.

The coppers prepared for planishing by this machine are taken separately, (the eyes having been previously cut out to a proper size by means of an iron punch, an hammer, and a lead block,) and each one is laid upon a lead of a correspondent diameter, and placed upon the anvil in such a manner that all the centres agree. The hammer, which has been hitherto retained at some height by an iron stay fixed in one of the timbers, and moving on a pivot, is then let fall, three or four times in quick succession, it being each time lifted up to the height of three feet or more, by means of the lever. The hammer is then again fastened by the stay, whilst the copper is turned over on the lead, after which the operation is repeated, and the copper is then taken off, and another laid down till the whole are gone through. The weight of the hammer, and the impetus acquired by its descent, remove most of the unevennesses in the coppers, yet cannot entirely remedy them: a strong and unequal spring will still be felt, and the metal being now rendered hard by the action of the hammer, annealing must again be resorted to, and the coppers must be pickled and cleaned as before. The machine is then used a second time in a similar way; and afterwards a third, a fourth, a fifth, and even a sixth and seventh time, according to the diameters of the coppers, or to the refractoriness of the metals, due care being taken properly to anneal and pickle them between every operation.

The coppers will now be found of a regular shape, and the spring in the metal tolerably uniform; it is essential, however, to the perfection of the plate, that the spring should be *entirely* uniform from edge to centre, otherwise the plate would warp and cockle in the fire. A kind of intermediate process must therefore be carried on between the taking the coppers from the machine, and before repeating the annealings. This is performed by means of a circular brass die, about a quarter of an inch in thickness, and from fifteen to eighteen inches in diameter, screwed firmly down to a strong oaken block, having three stout legs, placed triangular-wise, and of a sufficient height to use conveniently when the artist is in a standing posture. The die should have the same degree of curve as the machine, otherwise the effect produced by each would occasion a sort of reciprocal counteraction. The coppers, having passed through the machine, are placed in succession upon the die, and a wooden box-hammer (somewhat resembling that used by gold-beaters) with two faces, the one a circle about three inches over, the other cut away on the front edges, so as to leave only a portion about an inch or an inch and a quarter in breadth remaining in the middle, is then taken, and the copper is both rubbed and struck with it till the metal becomes too hard for any further impression to be made, and requires annealing. The circular end is used to strike the

copper with, which is done by short, quick beats of the hammer, the artist working from centre to edge, and communicating the necessary motion and direction to the coppers by means of the fingers of one hand, so extended over the work as to give the requisite command in guiding it: the other end is employed in rubbing the coppers strongly with a backward and forward action, under which they are moved upon the die by the fingers as before. Where the machine is not used, the planishing must then be entirely performed in the way just described, and great care must be taken, that in the rubbing, the coppers be not bent, which would occasion both additional labour, and further annealing. No positive direction can be given as to the number of times that the coppers must be annealed in the course of the planishing; as a general rule, it may be said that the larger the size, the more frequently must the annealings be repeated. For plates of from three to four inches, twice or thrice is commonly enough; from five to eight inches, about four or five times are requisite; for larger sizes, the annealings must be continued till the spring or action in the metal becomes uniform, as already mentioned. This is best determined by the regularity with which the copper will flap or jerk into the curve given by planishing when turned either side uppermost upon the die. When the planishing is completed, the coppers are cut exactly to the sizes required, and having been pickled and cleaned, they are then ready to be enamelled on. After the last annealing, it is best to planish but slightly, that the coppers may be left in a state of comparative softness.

For time-pieces, table clocks, and some others, *round* plates are commonly used, and in these cases it is necessary to have moveable brass dies formed into the curves required. Round plates are those which have a considerable rise in the centre, made by a pretty quick forcing up of the copper into a sort of shoulder about where the circles of the hours come, and afterwards continuing the rise more gradually. The bent spatula and the scratch brush are chiefly employed to set the coppers into these curves, and where the rise is very quick from the edge, the copper is sometimes turned up as in small dials, that the enamel may be the better retained in its place.

The quantity of enamel wanting for clock dials renders the grinding it a very laborious and tedious operation; especially as the hard kind only can be used with complete certainty. It is true that plates of from ten to twelve inches diameter have been made with glass enamel, where particular attention has been given to the *annealing up*, and to the *cooling down*, (phrases that will be presently explained,) and where the backing has been of a quality perfectly agreeing with the nature of the glass. Of the experiments made in this way, however, the success has not always been proportionate to the loss, and the few enamellers who have clock-furnaces cannot always be induced to repeat them.

The enamel for clock dials is broken down in a steel mortar, and afterwards cleansed and ground in an agate mortar, in a similar way to that prepared for watch plates. Sometimes, where the enamel is of a good quality, the *washings* are made use of for backing, and no bad consequence results, but this requires considerable care in the laying on as well as in properly drying, in order to prevent the surface of the back from rising in blisters, either entirely or partially. Washings is the name given to the almost impalpable powder which arises in grinding, and floats in the water, intermixed with the dust and minute hairs which are sure to fall into the mortar, and which renders it necessary that the enamel should be several times washed during the process by pouring off the buoyant matter from time to time, and introducing fresh water, from the tea-pot. Pure spring water ought always to be used, and a large bason provided for the reception of the washings.

In the best and largest kinds of work, the washings ought never to be used, as their great propensity to blister can hardly be counteracted; and when the blistering is considerable, the plates will assuredly *cockle*, or get out of shape. The peculiar fineness of the washings, also, occasions it to be very difficult to lay on as backing in an even manner. Where the enamel in substance only is used, the success of the work is rendered more certain; the additional expence therefore is fully balanced by the greater security.

The general way of putting on the enamel is to lay the copper upon a cloth, twice doubled, and placed upon a die or piece of board, for the conveniency of turning. The backing is then spread carefully over it by means of a small ivory or bone spoon, and when the whole surface is covered, the water is partially dried off by another cloth, and the enamel laid even by a large spatula, (see SPATULA,) finely polished. These operations are repeated till the back surface is sufficiently evened and dry; when the copper is turned, and the first coat laid on and evened in a similar manner. The work is then placed upon a planch for firing, and is next put into the annealing places in the upper part of the furnace, (see FURNACE *for Clock-Dials*,) where the humidity is gradually evaporated as the fire draws up. The planches are from a quarter of an inch to three quarters in thickness, in proportion to the size, and are either made of fine free-stone, or of a composition of Stourbridge clay, pipe clay, and *old stuff*, as the broken muffles, planches, &c. are called, pounded together in an iron mortar, and passed through a coarse sieve. The face of each planch is either flat or rubbed into a similar curve to that given to the coppers, and before the work is put on to it, a slight covering of whiting, dried, is sifted over it, through a small brass-wired sieve: this is done to prevent the enamel from sticking to the planch when in the act of fusion.

The muffle is *got up* or rendered hot with sea-coal, and when sufficiently vivid, which is known by its near approach to a white heat, the first coats are taken from the annealing holes by means of iron prongs, which are slid beneath the planches by a steady and careful motion, lest the enamel should be shook whilst in powder; to prevent this, also, a farther provision is frequently made by means of *irons*, as they are called in the business, which are placed below the planches, and having a round form, and a convex bottom, are extremely useful in moving the work, by admitting the prongs to be readily passed below them. The irons are adapted to the size of the planches, and are formed out of thin iron plates, and are cut into a circular shape; some portions of the metal, to render the irons less weighty, being wholly removed from between the rim and the centre, which from this circumstance appear to be connected by cross bars.

When the first coats are properly fired, which can only be determined from practice, they are replaced in the annealing holes, and there left for some hours to cool down, all the fire having been first raked out from the furnace. The operation of cooling down must be effected in a very gradual manner, for were it done too quickly, the plates would crack in different places, through the action of the metal upon the enamel. The particular cause of this cracking seems to arise from the surface of the enamel being too suddenly fixed by the cold air, to admit of that gradual adjustment to the contraction of the metal, which the latter, by retaining the heat longer than the enamel, renders necessary. On a similar principle, the annealing up of the second coats must be equally progressive; for should they be too

ſuddenly put into the fire, the metal, by expanding with the heat before the fuſion of the enamel has commenced, would cauſe the enamel to fly through its brittleneſs, and the ſurface would be thereby ſtreaked with cracks.

The enamel for ſecond coats, as in watch plates, muſt be ground finer than for firſt coats, yet not ſo fine as for backing. It is laid on with a ſpoon, and reduced to a ſmooth and equal ſurface by the ſpatula, in the ſame manner as above deſcribed; and the plate being enamelled with the requiſite attention, is fired a ſecond time, and gradually cooled down as before. The next operation is poliſhing.

Clock plates are poliſhed by a ſomewhat different proceſs than watch dials. When perfectly cold they are taken off the planches, and either carefully fixed upon a bed of wet ſand, ſo that not any hollow or vacancy is left below the plate, or imbedded in a ſimilar way with ſand upon wet flannel, twice or thrice doubled. When thus prepared, the ſurface is gradually worn even by means of fine ſilver ſand, paſſed through a ſieve, that the coarſer particles may be prevented from ſcratching the enamel, and poliſhing-ſtones formed of flint pebbles, ground at one end to a regular ſurface. The ſand is uſed with water, and the operation is performed by giving the poliſhing-ſtone a quick circular direction in progreſſive movements over every part of the plate, till the ſurface is evenly reduced, which is known by the gloſſyneſs being wholly worn off: this occupies from half an hour to an hour, or more, according to the ſize and previous evenneſs of the plate. Sometimes the poliſhing is accelerated by uſing pieces of lead or iron, as half-pound weights, for inſtance, in the early ſtage of the proceſs, and afterwards finiſhing with the flint; and that not only to give a ſmooth ſurface to the enamel, but likewiſe to remove the general ſtain or blackneſs which proceeds from the uſe of the lead or iron. When the poliſhing is completed, the plates are well waſhed and bruſhed, and afterwards made perfectly clean by ſome fine enamel being ground over the face of each with a ſmall mull or poliſhing-ſtone for about a quarter or half a minute; the operation being repeated twice or thrice, as may be neceſſary, and the looſe enamel being carefully wiped off with a ſmooth cloth or napkin, after the laſt cleanſing, inſtead of being waſhed away: this is done in order that the ſmall pores which are ſometimes laid open by poliſhing into the ſubſtance of the plate, may be filled up by the minute particles of enamel that eſcape the action of the cloth, but would be removed by the water. Whatever ſpecks or bliſters may be in the plate, are then opened with the diamond, and the holes neatly ſtopped with finely-ground enamel from a quill-point, as in watch-plates; the *ſtoppings up* being ſuffered to lie rather higher than the ſurface, to admit of the reduction in bulk occaſioned by the fuſion. The plates are now again put into the annealing places upon the planches; and the furnace being properly heated, are fired for the third and laſt time, before painting. In this latter firing, great care ſhould be taken that the enamel be not over-fired, which would occaſion a freckled appearance in the plate, when held againſt the light; and if the work is drawn out from the muffle after the fuſion has commenced, and again returned to complete it, the air will be found to have given additional richneſs to the gloſſyneſs of the ſurface. The preciſe time required for firing poliſhed plates can only be known from practice; thoſe on which the fineſt poliſhing-ſand was uſed, and, of courſe, where the ſcratches are leſs deep, wanting leſs heat than when the ſand has been employed in a rougher ſtate. After firing, the finiſhed plates are returned to the annealing-holes, and gradually cooled down for painting on. See PAINTING *of Clock and Watch Plates*.

In the making of *fluxed plates* for enamel-paintings, ſimilar methods of planiſhing are practiſed to thoſe already detailed; and ſimilar or even increaſed care muſt be taken in deſtroying or regulating the ſpring of the copper. Fluxed plates are commonly either ſquare or oval: in the ſquare ones, about an eighth of an inch, or ſomewhat more, ſhould be cut off each angle of the copper, previous to enamelling, to prevent the danger of breaking them. In preparing them for the flux, every thing is conducted in the ſame way as for clock-dials, till they are poliſhed off, when, inſtead of firing them in their poliſhed ſtate, the flux is laid on as a third coat. In grinding the flux, very particular attention muſt be given to keep it free from dirt; and the grinding muſt be continued till the flux becomes extremely fine, as it will not otherwiſe flow to an even ſurface, when expoſed to the fire, without a more intenſe heat than the ſubſtance will well bear. The flux indeed requires a peculiar delicacy of treatment, and the firing of the fluxed plates muſt be managed with great caution and nicety. The heat which they require in fuſion is much ſtronger than that for enamels only; but the exact point of time for withdrawing them from the furnace muſt be dexterouſly ſeized, leſt the flux ſhould fall into freckles. It is not cuſtomary to poliſh off the flux, as by ſo doing it would be deprived of ſome portion of its brilliant richneſs; yet that perhaps would be in ſome meaſure compenſated for, by the ſuperior evenneſs that would be attained. Fluxed plates muſt be cooled down with great care, as the brittleneſs of the upper coating renders them more liable to crack when too ſuddenly made cool. In fluxing, hard enamel muſt always be uſed; as the flux will not agree with glaſs enamel, but cracks in circles as it grows cold. See FLUX.

The greater ductility of gold, and its ſuperior mellowneſs of colour, render it by far the beſt metal that could be employed for the baſis of fluxed plates; though, on account of the expence, it is ſeldom uſed. For naked figures, portraits, or other ſubjects, where much fleſh is exhibited, gold plates ought to be excluſively employed, as their rich hue would ſave conſiderable labour in the painting.

Till the preſent age, fluxed plates were ſeldom made of a larger ſize than four or five inches; but ſince the art of enamel-painting has been carried to ſuch great perfection by Mr. Bone, enamel-painter to the king and the prince of Wales, they have been progreſſively increaſed in extent for his uſe, and are now made of every ſize up to twelve and fourteen inches. The largeſt ever completed meaſures eighteen inches by ſixteen and a half; and Mr. Bone is now employed in painting it from Titian's famous picture of Bacchus and Ariadne, in the collection of lord Kinnaird. See PAINTING *on Enamel*.

In chuſing enamels for uſe, great experience is neceſſary: indeed the moſt expert practitioner may be deceived, unleſs he make the requiſite trials by aid of the furnace. Some enamels can only be employed alone; others may be uſed for the upper coats, but require a ſtronger kind for the backs; and ſome can be uſed only for backing. Should a new ſort be proffered for uſe, experiment alone is the criterion by which its qualities can be determined. In a ſimilar manner, ſome fluxes will only agree with particular enamels; others muſt be uſed ſeparately; and others again muſt be mixed in grinding, before they can be employed with certainty.

In every branch of enamelling, it is eſſential that the copper, or other metal employed to enamel on, ſhould be of a proper thickneſs. Should the metal be too thick, the plates will always crack, either in their ſecond coats, or in their poliſhed ſtate; and ſhould it be too thin, they would

be extremely likely to warp from the too powerful action of the enamel. The due medium can only be ascertained by practice; for even the different kinds of enamel will require a difference in the thickness of the metal.

The proper management of the fire, and the mode by which the muffle is heated, will be explained under the words FURNACE and MUFFLE; it need only be stated here, that the time necessary to *get up* a clock furnace varies from about an hour and a half to two and three hours, or more, according to the intensity of the draught, the method of stoking, and the quality of the fuel. The work is turned in the muffle by means of spring tongs, so that each part may have a regular and due heat; and it is returned into the annealing places with the prongs. Should many plates be fired at one time, the labour will be found to be very severe, and the heat too powerful; as it carries a flux of blood to the head, and occasions languor and oppression throughout the whole frame.

Engine

ENGINE, in *Mechanics*, a compound machine, confifting of feveral fimple ones, as wheels, fcrews, levers, or the like, combined together, in order to lift, caft, or fuftain a weight, or produce fome other confiderable effect, fo as to save either time or force.

The word is formed of the French *engine;* of the Latin *ingenium*, wit; becaufe of the ingenuity required in the contrivance of engines, to augment the effect of moving powers.

The kinds of engines are innumerable; fome for war, as the balifta, catapulta, fcorpio, aries, &c. others for the arts of peace, as mills, cranes, preffes, clocks, watches; engines to drive piles, to bore cannon and water-pipes (fee BORING), to raife water, wheel and water-works; to extinguifh fire, fee FIRE-*engine*, &c. See HYDROCANISTERIUM. See STEAM-*engine*, &c. .See alfo INSTRUMENT.

ENGINE *for cutting Wheels*. See CUTTING-*Engine*.

ENGINE *for cutting Fufees*. See FUSEE-*Engine*.

ENGINE *for ornamenting a Watch-cafe*. See ROWS-*Engine*, or ROSE-*Engine*.

ENGINE *for dividing Circles, Quadrants, Sextants*, and *Octants*. It is not our intention in this place to enter into the hiftory of the different methods of dividing aftronomical inftruments into degrees and their fub-divifions, as fucceffively practifed by Tycho Brahe, Hevelius, Dr. Hook, Mr. Abraham Sharp, Olaus Roemer, Mr. Graham, Mr. Jon. Siffon, Mr. Bird, Mr. Ramfden, and Mr. Troughton, without the aid of an engine; but, as we propofe to treat the fubject at fome length under our article GRADUATION *of Aftronomical Inftruments*, we beg leave to refer the reader to that head for fuch particulars as relate to the manual operations performed by the beam-compafs and otherwife, which are neceffary for graduating all circles and other inftruments, that are too large to be graduated by an engine.

Among all the improvements in chronometers and nautical inftruments, that owed their origin, during the laft century, to the munificent encouragement of the honourable Board of Longitude, there is none that has fo much contributed to the intereft of navigation, confidered as a fcience, as the engine at prefent to be defcribed; the facility, and at the fame time the accuracy, with which the meafuring portion of any nautical inftrument, however portable, can now be divided by our beft engines, are truly aftonifhing; the fine dividing ftrokes, which, in many inftances, are fcarcely vifible to, and not legible by the naked eye, when magnified by a fuitable lens, are perceived to be laid down with fuch perfect equality, as to relative diftances, that no one who has not examined the means by which they were effected, can conceive the poffibility that the expedition, with which the divifions are made, is equal to the accuracy with which they are meafured and marked down. In Mr. Smeaton's paper, read to the Royal Society of London, on Nov. 17, 1785, on the "Graduation of Aftronomical Inftruments," he mentions an engine, made by Mr. Henry Hindley of York, which indented the edge of any circle in fuch a way, that a fcrew with fifteen threads acting at once, would, by means of a micrometer, read off any given number of divifions, fo as to anfwer the purpofe of fub-dividing the circle. It does not, however, appear that this engine, though it divided the circles of Hindley's equatorial inftruments, was intended or adapted fo much for graduating circles as for cutting the teeth of wheels in clock-work. (See CUTTING-*Engine*.) The year in which it was feen

by Mr. Smeaton was 1741, and, consequently, was in Graham's time, who died in 1751. According to the same author, Mr. Ramsden, in consequence of the reward offered by the Board of Longitude to Mr. Bird, for his method of dividing, in the year 1760, turned his thoughts towards the contrivance of an engine that would divide nautical instruments with sufficient accuracy, without the tediousness of manipulation. Accordingly, considering the nature and properties of the endless screw, and probably contemplating what Hindley had previously done in this way, he completed an engine with an indented plate, or wheel, of thirty inches diameter, which, though it did not completely answer his expectations to their full extent, yet was found very useful for dividing theodolites and such common instruments with great facility. This was effected before the spring of 1768, and, in 1774, a much larger and better engine was produced, with an indented plate of 45 inches diameter, which divided a sextant for Mr. Bird's examination so accurately, that the Board of Longitude, ever ready to remunerate any successful endeavour to promote the lunar method of determining the longitude at sea, did not hesitate to confer an handsome reward on the inventor, but on condition that the said engine might be at the service of the public, and that Mr. Ramsden would publish an explanation of his method of making and using it, which he accordingly did in a quarto pamphlet in the year 1777. The sum of money given to Mr. Ramsden was 615*l.*, of which 300*l.* was considered as a reward for his improvement in the art of dividing instruments by means of his engine, and the remaining 315*l.* was paid in consideration of his making over the property of the said engine to the Commissioners of Longitude, for the good of the public. The description which Mr. Ramsden published, being short and explicit, cannot well be abridged, and the drawings, intended as a guide for other artists to work by, are explanatory of all the parts of the engine, as detached from one another; we have therefore given reduced engravings of all the figures, as they were originally arranged, and propose to copy the description without any other alteration than what the references to our plates required.

Mr. Ramsden's Engine.—"This engine consists of a large wheel of bell-metal, supported on a mahogany stand, having three legs, which are strongly connected together by braces, so as to make it perfectly steady; *fig.* 1. *Plate* VII. of *Engines*, is a perspective representation of the body thus united. On each leg of the stand is placed a conical friction-pulley, whereon the dividing-wheel rests: to prevent the wheel from sliding off the friction-pulleys, the bell-metal centre under it turns in a socket on the top of the stand. The circumference of the wheel is ratched or cut, by a method to be hereafter described, into 2160 teeth, in which an endless screw acts. Six revolutions of the screw will move the wheel a space equal to one degree. Now a circle of brass being fixed on the screw-arbor, having its circumference divided into 60 parts, each division will answer to a motion of the wheel of ten seconds; six of them will be equal to a minute, &c. Several different arbors of tempered steel are truly ground into the socket in the centre of the wheel. The upper parts of the arbor, that stand above the plane, are turned of various sizes, to suit the centres of different pieces of work to be divided. When any instrument is to be divided, the centre of it is very exactly fitted to one of these arbors, and the instrument is fixed down to the plane of the dividing wheel, by means of screws, which fit into holes made in the radii of the wheel for that purpose. The instrument being thus fitted on the plane of the wheel, the frame which carries the dividing-point is connected at one end by finger-screws with the frame which carries the endless screw; while the other end embraces that part of the steel arbor which stands above the instrument to be divided, by an angular notch in a piece of hardened steel; by these means both ends of the frame are kept perfectly steady and free from shake.

The frame carrying the dividing-point, or tracer, is made to slide on the frame which carries the endless screw to any distance from the centre of the wheel, that the radius of the instrument to be divided may require, and may be there fastened by a pair of clamps; and the dividing-point, being connected with the clamps by the double-jointed frame, admits a free and easy motion towards or from the centre, for cutting the divisions without any lateral shake. From what has been said it appears, that an instrument thus fitted on the dividing-wheel may be moved to any angle by the screw and divided micrometer circle on its arbor, and that this angle may be marked on the limb of the instrument with the greatest exactness by the dividing-point, which can only move in a direct line tending to the centre, and is altogether freed from those inconveniences that attend cutting by means of a straight edge. This method of drawing lines will also prevent any error that might arise from an expansion or contraction of the metal, during the time of dividing. The screw-frame is fixed on the top of a conical pillar, which turns freely round its axis, and also moves freely towards or from the centre of the wheel, so that the screw-frame may be entirely guided by the frame which connects it with the centre: by these means any eccentricity of the wheel and the arbor would not produce any error in the dividing; and by a particular contrivance, hereafter described, the screw, when pressed against the teeth of the wheel, always moves parallel to itself; so that a line joining the centre of the arbor and the dividing-point, continued, will always make equal angles with the screw. The rest of the parts are represented in *Plates* VIII. and IX. of *Engines*, where the figures are numbered in succession from 2 to 14 inclusively, which are more easily referred to than the figures in the original plates. *Fig.* 2 is a plan of reduced dimensions, of which *fig.* 3 represents a section on the line II A. The large wheel, A, is 45 inches in diameter, and has 10 radii, each supported by edge bars, as seen in *fig.* 3. These bars and radii are connected by the circular ring B, 24 inches in diameter, and 3 deep; and, for greater strength, the whole is cast in one piece in bell-metal. As the whole weight of the wheel, A, rests on its ring B, the edge-bars are deepest where they join it; and from thence their depth diminishes, both towards the centre and circumference, as seen in the figure. The surface of the wheel, A, was worked very even and flat, and its circumference turned true. The ring C, of which a section is seen in *fig.* 3, made of fine brass, was fitted very exactly on the circumference of the wheel, and was fastened thereon with screws, which, after being screwed as tight as possible, were well rivetted. The face of a large chuck being turned very true and flat in the lathe, the flattened surface, A, of the wheel was fastened against it with hold-fasts; and the two surfaces and circumference of the ring C, a hole through the centre, and the plane part round it, together with the lower edge of the ring B, were all turned at the same time. D is a piece of hard bell-metal, having the hole that receives the steel-arbor made very straight and true. This bell-metal was turned very true on its arbor, and its face, that rests against the wheel, was made very flat, so that the steel-arbor might stand perpendicular to the plane of the wheel: this bell-metal was fastened to the wheel by six steel screws. A brass socket, Z, is fastened on the centre of the mahogany stand,

and receives the lower part of the bell-metal piece D, being made to touch the bell-metal in a narrow part near the mouth, to prevent any obliquity of the wheel from bending the arbor: good fitting is by no means neceffary here, fince any fhake in this focket will produce no bad effect, as will appear when the cutting-frame is defcribed. The wheel was then put on its ftand, the lower edge of the ring, B, refting on the circumference of the three conical friction-pulleys W, to facilitate its motion round its centre. The axis of one of thofe pulleys is in a line joining the centre of the wheel and the middle of the endlefs fcrew, and the other two placed fo as to be at equal diftances from each other. F is a block of wood (*fig.* 1.), ftrongly faftened to one of the legs of the ftand; the piece, *g* (*figs.* 1 and 12.), is fcrewed to the upper fide of the block, and has half holes, in which the tranfverfe axis, *h*, (*figs.* 1 and 11.) turns; the half holes are kept together by the fcrews *i*. The lower extremity of the conical pillar, P, (*figs.* 1 and 11.) terminates in a cylindrical fteel pin *k*, which paffes through and turns in the tranfverfe axis *h*, and is confined by a cheek and fcrew. To the upper end of the faid conical pillar is faftened the frame G, (*figs.* 5 and 9.), in which the endlefs fcrew turns; the pivots of the fcrew are formed in the manner of two frufta of cones joined by a cylinder, as reprefented at X, in *fig.* 9. Thefe pivots are confined between half holes, which prefs only on the conical parts, but do not touch the cylindrical parts; the half holes are kept together by fcrews, *a*, *a*, which may be tightened at any time, to prevent the fcrew from fhaking in the frame. On the fcrew-arbor is a fmall wheel of brafs, K, having its outfide edge divided into 60 parts, and numbered at every 6th divifion with 1, 2, &c. to 10. The motion of this wheel is fhewn by the index, *y*, on the fcrew-frame G. H reprefents part of the ftand (*fig.* 1.) having a parallel flit in the direction towards the centre of the wheel, large enough to receive the upper part of the conical brafs pillar P, which carries the fcrew and its frame; and as the refiftance, when the wheel is moved by the endlefs fcrew, is againft that fide of the flit, H, which is towards the left hand, that fide of the flit is faced with brafs, and the pillar is preffed againft it by a fteel fpring on the oppofite fide: thus is the pillar ftrongly fupported laterally, and yet the fcrew may be eafily moved from or againft the circumference of the wheel, and the pillar will turn freely on its axis, to take any direction given it by the frame L, lying over the wheel in *fig.* 1, and feen more diftinctly in *fig.* 13.

At each corner of the piece I, feen in *fig.* 1, and alfo detached in *fig.* 8, are as many fcrews, *n*, of tempered fteel with polifhed conical points: two of them turn in conical holes in the fcrew-frame, near *o*, *fig.* 9; and the points of the other two turn in holes in the piece Q, *fig.* 7: the fmall end fcrews, *p*, are of fteel, which, being tightened, prevent the conical pointed fcrews from unturning, when the frame is moved. The brafs frame L, *figs.* 1 and 13, ferves to connect the endlefs fcrew, its frame, &c. with the centre of the wheel; each arm of this frame is terminated by a fteel fcrew, that may be paffed through any of the holes, *q*, in the piece Q, *fig.* 7, as the thicknefs of the work to be divided on the wheel may require, and are faftened by the finger-nuts *r*, feen in *figs.* 1 and 2. At the other end of this frame is a flat piece of tempered fteel *b*, wherein is an angular notch: when the endlefs fcrew is preffed againft the teeth of the circumference of the wheel, which may be done by turning the finger-fcrew S, feen in *figs.* 1 and 2, to prefs againft the fpring *t*, this notch embraces and preffes againft the fteel-arbor *d*. This end of the frame, too, may be raifed or depreffed, by moving the triangular or prifmatic flide *u* (*fig.* 14.), which may be fixed at any height by the four fteel fcrews *v*. The bottom of this flide has a notch *k*, having its plane parallel to the endlefs fcrew; and by the point of the arbor *d*, refting in this notch, this end of the frame is prevented from tilting: the fcrew, S, alfo is kept faft by the finger-nut *w*, in *fig.* 2.

The teeth on the circumference of the wheel were cut by the following method. Having confidered what number of teeth on the circumference would be moft convenient, which in this engine is 2160 or 360 × 6, I made, fays Mr. Ramfden, two fcrews of the fame dimenfions of tempered fteel, the interval between the threads of which being fuch as I knew by calculation would come within the limits of what might be turned off the circumference of the wheel; one of thefe fcrews, which was intended for ratching or cutting the teeth, was notched acrofs the threads, fo that the fcrew, when preffed againft the edge of the wheel and turned round, cut in the manner of a faw. Then having a fegment of a circle a little greater than 60°, of about the fame radius with the wheel, and its circumference made true from a very fine centre, I defcribed an arch near the edge, and fet off the chord of 60° on this arch. This fegment was fubftituted for the wheel, and had its edge ratched or indented; and the number of revolutions and parts of the fcrew head contained within the arch of 60° were counted. The radius was corrected in the proportion of 360 revolutions, which ought to have been in 60°, to the number actually found; and the radius fo corrected was taken in a pair of beam compaffes: while the wheel was on the lathe, one foot of the compaffes was put in the centre, and with the other a circle was defcribed on the ring; then half the depth of the threads of the fcrew being taken in the dividers, was fet from this circle outwards, and another circle was defcribed cutting this point; a hollow was then turned on the edge of the wheel of the fame curvature as that of the fcrew, at the bottom of its threads; the bottom of this hollow was turned to the fame radius as the outward one of the two circles before-mentioned.

The wheel was now taken off the lathe, and the bell-metal piece D, *fig.* 3, was again fcrewed to its place, not to be removed any more. From a very exact centre, a circle was defcribed on the ring C, *fig.* 4, about $\frac{4}{10}$ths of an inch within where the bottom of the teeth would come; this circle was divided with the greateft poffible exactnefs, firft into 5 parts, and each of thefe again into 3; thefe parts were then bifected 4 times; *i. e.* fuppofing the whole circumference of the wheel to contain 2160 teeth, a fifth part would be 432, a fifteenth part (or 5 × 3) would be 144, and this laft number bifected four times would give 72, 36, 18, and 9 refpectively; but as it was apprehended that fome inaccuracy would arife from quinquefection and trifection, another circle was defcribed on the fame ring, at $\frac{1}{10}$th of an inch within the former circle, and divided by continual bifections into the portions 2160, 1080, 540, 270, 135, $67\frac{1}{2}$, and $33\frac{3}{4}$; and as the fixed wire, to be defcribed prefently, croffed both the circles, it was a check on their agreement at every 135 revolutions, and after ratching at every $33\frac{3}{4}$; but as no fenfible difference was perceived in the two circles, the former was chofen for ratching: and as the coincidence of the fixed wire with an interfection would be more exactly determined than with a dot or divifion, the interfections in both circles were ufed.

The arms of the frame L, *figs.* 1 and 13, were connected by a thin piece of brafs $\frac{3}{4}$ of an inch broad, having a hole of $\frac{4}{10}$ths of an inch diameter in the middle; acrofs this hole a filver wire was fixed exactly in a line to the centre of the

wheel; the coincidence of this wire with the interfections was examined by a lens of $\frac{7}{10}$ths of an inch focus, fixed in a tube, that was attached to one of the arms L. Now a handle, or winch, being fixed on the end of the fcrew-arbor, the divifion marked 10 on the circle K was fet to its index, and, by means of a clamp and adjufting fcrew for that purpofe, the interfection marked 1 on the circle C was fet exactly to coincide with the fixed wire; the fcrew was then carefully preffed againft the circumference of the wheel, by turning the finger-fcrew S; then, the clamp being removed, the fcrew was turned by its handle juft 9 revolutions, till the interfection marked 240, *fig.* 4, came nearly to the wire; the finger-fcrew S was now turned back, and the dividing fcrew releafed from the edge of the wheel, which was here turned back till the interfection marked 2 exactly coincided with the wire; the divifion 10 on the micrometer circle was then fet to its index as before, and the fcrew preffed againft the edge of the wheel by the finger-fcrew S; then, the clamps being removed, the fcrew was turned a fecond 9 revolutions, till the interfection marked 1 nearly coincided with the fixed wire; the fcrew was again releafed, and the fame operation was repeated till the teeth were faintly marked all round the circumference of the wheel. The impreffion was made deeper by thus going three times round; after which the wheel was ratched continually round 300 times in the fame direction, without difengaging the fcrew, when the teeth were found fufficiently indented. Now, it is evident, that, if the circumference of the wheel were even a whole tooth or ten minutes fpace greater than the fcrew would require, this error would, in the firft inftance, be reduced to $\frac{1}{240}$th part of a revolution, or two feconds and a half; and thefe errors or inequalities of the teeth were equally diftributed round the wheel at the diftance of 9 teeth from each other; but, as the fcrew in ratching had continually hold of feveral teeth at the fame time, and as thefe were conftantly changing, the above-mentioned inequalities foon corrected themfelves, and the teeth were reduced into a perfect equality.

The piece of brafs which carries the wire was now taken away, and the cutting-fcrew alfo removed, and replaced by the plane one of the fame dimenfions; on one end of its arbor was put the micrometer circular plate divided into 60, and numbered at every fix divifions, as already ftated; and on the other end was placed a ratchet-wheel of 60 teeth, feen in *fig.* 6, which is covered by the hollowed circle *d*, carrying two clicks, that catch upon the oppofite fides of the ratchet, when the fcrew is to be moved forwards. The cylinder S, *figs.* 5 and 9, turns on a ftrong fteel arbor F, feen in *fig.* 5, which paffes through, and is firmly fcrewed to the piece Y; this piece, for greater firmnefs, is attached to the fcrew frame G by the braces *v*: a fpiral groove or thread is cut on the outfide of the cylinder S, which ferves both for holding the ftring, and alfo for giving motion to the lever J on its centre, *figs.* 9 and 10, by means of a fteel tooth *n* that works between the threads of the fpiral. To the lever is attached a ftrong fteel pin *m*, *fig.* 10, on which a brafs focket *r* turns: this focket paffes through a flit in the piece *p*, and may be tightened in any part of the flit by the finger-nut *f*: this piece ferves to regulate a number of revolutions of the fcrew for each tread of the treadle R, feen in *fig.* 1. T, in *fig.* 1, is a brafs box, containing a fpiral fpring: a ftrong gut is faftened and turned three or four times round the circumference of this box; the gut then paffes feveral times round the cylinder S, *figs.* 1 and 9, and from thence down to the treadle R. Now, when the treadle is preffed down, the ftring pulls the cylinder S round its axis, and the clicks laying hold of the teeth on the ratchet, carry the fcrew round with it, till, by the tooth *n* working in the fpiral groove, the lever J is brought near the wheel *d*, *fig.* 6, and the cylinder is ftopped by the fcrew-head *x*, *fig.* 9, ftriking on the top of the lever J: at the fame time the fpring is wound up by the other end of the gut paffing round the box T, *fig* 1. Now, when the foot is taken from the treadle, the fpring in the box unbending itfelf, pulls back the cylinder, the clicks leaving the ratchet and attached fcrew at reft till the piece *t* ftrikes on the end of the piece *p*, *fig.* 10; and the number of revolutions of the fcrew at each tread is limited by the number of revolutions that the cylinder is allowed to turn back before the ftop ftrikes on the piece *p*. When the endlefs fcrew is moved round its axis with a confiderable velocity, it will continue that motion a little after the cylinder S is ftopped; to prevent which angular motion, the angular lever *n* was made, that when the lever J comes near to ftop the fcrew *x*, it, by a fmall chamfre, preffes down the piece *x* of the angular lever; this brings the other end *n* of the fame lever forwards, and ftops the endlefs fcrew by the fteel pin μ ftriking on its top; the foot of the lever is again raifed by a fmall fpring preffing on the brace *v*.

Two clamps D, *fig.* 13, connected by the piece *a*, *fig.* 1, flide, one on each arm of the frame L, and may be fixed at pleafure by the four finger-fcrews *i*, which prefs againft fteel fprings, to avoid fpoiling the arms; the piece *q*, *fig.* 13, is made to turn without fhake between the two conical pointed fcrews *f*, *f*, fet faft by the finger-nuts N, N. The piece M is made to turn on the piece *q*, by the conical pointed fcrews refting in the hollow centres *e*, *e*. As there is frequent occafion to cut divifions on inclined planes, for that purpofe the piece γ, in which the tracer or dividing point is fixed, has a conical axis at each end, which turn in half holes; fo that when the tracer is fet to any inclination, it may be fixed there, by tightening the fteel fcrews $\beta\beta$."

Subfequently to the time of Mr. Ramfden's dividing engine being conftructed, Mr. Edward Troughton conftructed one to anfwer the fame purpofe, which it does in the moft perfect manner; and it was our intention to have defcribed it alfo in this place, but on application to him for permiffion to infpect its parts and manner of operating, we were forry to learn that he has pledged himfelf to give an account of it himfelf in another work.

Engine (by Ramfden) *for cutting the Screws of the circular Dividing-Engine.*—We mean not to enter here into the hiftory of the fcrew-engine, as it may be, and has been applied to various purpofes, but to defcribe the engine made and ufed by Mr. Ramfden for making the individual fcrews which he ufed for ratching his engine for dividing circles, &c., and for meafuring the angular diftance on his circle when ratched. This apparatus, indeed, may be confidered as an appendage to the other, and therefore ought to be introduced in this place. *Fig.* 1. of *Plate* X. of *Engines*, reprefents this engine as feen from one fide of reduced dimenfions; and *fig.* 2, the fame as feen from above, of the fame dimenfions. A reprefents a triangular bar of fteel, to which the triangular holes in the pieces B and C are accurately fitted, and may be fixed on any part of the bar by the fcrew D. E is a piece of fteel whereon the fcrew is intended to be cut, which, after being hardened and tempered, has its pivots turned in the form of two frufta of cones, as reprefented in the drawings of the dividing-engine. Thefe pivots were very exactly fitted to the half holes F and T, which were kept together by the fcrews Z. H reprefents a fcrew of untempered fteel, having a pivot I, which turns in the hole K. At the other end of the fcrew is a hollow centre, which

receives the hardened conical point of the steel pin M. When this point is sufficiently pressed against the screw, to prevent its shaking, the steel pin may be fixed by tightening the screws Y. N is a cylindrical nut, moveable on the screw H, which, to prevent any shake, may be tightened by the screws O. This nut is connected with the saddle-piece P, by means of the intermediate universal joint W, through which the arbor of the screw H passes. A front view of this piece, with a section across the screw-arbor, is represented at X, *fig.* 3. This joint is connected with the nut by means of two steel slips S, which turn on pins between the cheeks T, on the nut N. The other end of these slips S turn in like manner on pins *a*. One axis of this joint turns in a hole in the cock *b*, which is fixed to the saddle-piece, and the other turns in a hole *d*, made for that purpose in the same piece on which the cock *b* is fixed. By these means, when the screw is turned round, the saddle-piece will slide uniformly along the triangular bar A. K is a small triangular bar of well-tempered steel, which slides in a groove of the same form on the saddle-piece P. The point of this bar or cutter is formed to the shape of the thread intended to be cut on the endless screw. When the cutter is to take proper hold of the intended screw, it may be fixed by tightening the screw *e*, which press the two pieces of brass G upon it. Having measured the circumference of the dividing-wheel, it was found to require about one thread in a hundred, coarser than the guide-screw H. The wheels on the guide-screw arbor H, and that on the steel arbor E, on which the screw was to be cut, were proportioned to each other to produce that effect, by giving the wheel L 198 teeth, and the wheel Q 200. These wheels communicated with each other by means of the intermediate wheel R, which also served to give the threads on the two screws the same direction. The saddle-piece P is confined on the bar A by means of the pieces *g*, and may be made to slide with a proper degree of tightness by the screws *n*.

ENGINE *for cutting the Screw of Ramsden's Engine for dividing Straight Lines.*—The exactness of the straight line engine, as made by Ramsden, depends very much on the correctness of the endless screw, which requires some properties that are not absolutely necessary in the endless screw for the *circular engine*. In that, as there are but a few threads of the endless screw engaged in the teeth of the wheel, it required only that those threads should have a similar inclination to the axis of the screw all round; but in the straight-line engine, where the whole length of the screw is engaged in the moveable plate, it is necessary that the distances also between the threads should be precisely the same throughout the whole length of the screw: as this is effected in a manner in some respects different from the mode of cutting the screw we have just described, we shall subjoin it here, that the reader may take a comparative view of the two methods adopted by that great artist Ramsden. In *fig.* 1. of *Plate* XI. of *Engines*, is a plan of the engine for cutting the screw for dividing *straight lines;* and in *fig.* 2, is an elevation of the same. The section, as given in the original account published in 1779, does not seem to be necessary for explaining the engine, and is therefore omitted in our account. A, in *fig.* 1, represents a strong circular plate of brass, having its edge ratched, as described in our account of the circular dividing-engine; on its centre is firmly fixed the pulley B by four screws, having a groove turned on its cylindrical part, perfectly concentric with the plate A. C, in *fig.* 2, is a steel axis two feet long, terminating in a point, whereon it rests; the upper part of the axis being firmly screwed to the plate A, and turning in the collar D. E represents an endless screw, *fig.* 1, which being turned on its horizontal axis, moves the circular plate A round its centre: F is a circular divided small plate, or micrometer-head, which may be turned with or without the endless screw; and on the other end of this screw-arbor is a large pinion *a*, with levelled teeth on its edge, together with the winch X to turn it by. G, seen in both figures, is a triangular bar of steel, which passes over the circular plate A, and is firmly screwed to the frame of the engine at H, *fig.* 1, and I, *fig.* 2. K is a piece of steel forming the arbor of the screw intended to be cut, having a wheel L, on one end acting with the pinion *a* before-mentioned. M and N, *fig.* 1, are two strong pieces of brass, in which the arbor just mentioned turns, and are firmly fixed to the triangular bar G, by means of the screws *n*, *n*, seen at I, in *fig.* 2. O, seen in both figures, is a piece of brass that slides on the triangular bar G, the two extremities of which are made exactly to fit the bar; it slides regularly thereon, and is prevented from rising by the two spring pieces *c*, *c*; near one end of the piece O is an angular groove *q*, *fig.* 1, that holds the tool by which the threads are cut, and is pointed with a diamond, in order to cut the steel after it is hardened and tempered: the cock *w* serves to fasten the tool, which may be set to take proper hold on the steel by turning the finger-screw *s*, and is fixed there by the screw *v*.

To make a perfect screw, it is only required to give the point that cuts the threads an uniform motion parallel to itself, and also to the axis of the intended screw, and that this motion be proportioned to the revolutions of the intended screw as the number of threads may require. To effect this, a piece of thin tempered steel *t*, exactly of the same thickness throughout, is fastened to the slide O at *r*; the other end of the spring being fastened to the pulley B in the groove: now while the circle A, with the pulley, is turned round its centre by turning the endless screw to the right hand, the spring *t* draws the slider O, with the attached cutter *q*, along the triangular bar; at the same time the steel-arbor K of the screw to be cut revolves by means of the communication of its wheel L with the revolving pinion *a*.

The screw, E, of the circular plate has 20 threads *per* inch, therefore if the number of teeth on the pinion, *a*, be to the number in the wheel L, as the number of teeth on the circular plate, A, is to the number of 20ths of an inch round the circumference of the pulley B, allowing for part of the thickness at the spring *t*, the spaces between each of the threads of the screw to be cut will be also 20ths of an inch. The size of the pulley, B, was determined thus: the endless screw, E, being disengaged from the circular plate A, the slider, O, was drawn back till the end of it came nearly to the piece M; the endless screw was again engaged in the plate A; then having two very small dots on the slider O, set off parallel to one side, at exactly five inches distance from each other, the slider was moved by turning the endless screw E, till one of its dots was bisected by a small silver wire fixed across a hole made in a thin piece of brass fast to the piece N; then O on the micrometer head, F, being put to the index without moving the screw, the pulley was tried and reduced, till just 600 revolutions of the endless screw, E, brought the second dot to be exactly bisected by the fixed wire. These bisections were examined by a lens of half an inch focus, set in a small brass tube, that was fixed perpendicularly over the wire.

ENGINE *for dividing straight Lines, by Ramsden.*—When Mr. Ramsden had succeeded in dividing sextants, &c. by his circular dividing engine, and was rewarded by the honourable Board of Longitude, he turned his mind to-

wards the contrivance of an engine that would divide ſtraight lines into any number of aſſignable parts, and that might be uſeful in laying down with extreme accuracy the lines of ſines, tangents, ſecants, &c. on ſectors and plane ſcales. The project was realized, and the account was ordered to be publiſhed by the Board of Longitude, in the year 1779. We do not find, however, that the original model, which we come now to deſcribe, has been found deſirable to copy by ſucceeding mathematical inſtrument makers: more ſimple and leſs expenſive means have been adopted, which are found to anſwer practically as good a purpoſe. A beam-compaſs, aided by proper tables, is quite accurate enough for the niceſt purpoſes of dividing unequal, as well as equal, diviſions by biſection; and a pattern once carefully laid down can be uſed, for transferring the diviſions on the common caſes of inſtruments, with greater facility than the engine itſelf can be worked; and, provided great care be taken to prevent the parallax of the transferring point, the accuracy will be ſufficient for all ordinary uſes. This engine, which profeſſes to divide any line without an error of $\frac{1}{400}$-th of an inch, has its principal parts repreſented in *Plate* XII. of *Engines;* where *fig.* 1, repreſents a plan of the dividing portion, as ſeen from above; *fig.* 2, an elevation of the ſame ſeen acroſs; and *fig.* 3, the under ſide of *fig.* 1, when turned up. The original account contains ſome ſections, which are more uſeful for the workmen as patterns, than for a general deſcription, which may diſpenſe with them altogether. A, in *fig.* 1, is a ſtrong braſs plate, 27 inches long, 4 broad, and $\frac{7}{10}$ths thick; worked exceedingly flat, and of the ſame thickneſs throughout, with its two edges parallel. One of theſe edges is ratched, or cut into teeth, of which there are juſt 20 in an inch, and is moved by an endleſs ſcrew, containing juſt 20 threads in an inch, which actuates the teeth. (See ENGINE *for cutting the Screw of Ramſden's ſtraight-line Engine.*) Each revolution of the endleſs ſcrew round its axis will move the plate $\frac{5}{100}$ths of an inch along an iron frame, hereafter to be deſcribed. A micrometer head is fixed at one end of the ſcrew arbor, divided into 50 diviſions, which, by means of a vernier ſubdividing into 5 parts, meaſures $\frac{2}{10000}$ths of an inch along the frame. Any rule or other inſtrument may be faſtened on this plate, and may have a line drawn on it divided by a point or tracer, fixed in a proper frame, whereby it has a rectilinear motion without any lateral ſhake. When lines are to be divided by diviſions not commenſurable with Engliſh inches, which conſtitute the ſcale, the line to be ſo divided may be laid down, not parallel to the plate A, but obliquely, ſo as to make an angle with it, or become the hypothenuſe line of a right-angled triangle; which line, by calculation, ſhall be to the baſe as the denomination of meaſure, when longer, is to the Engliſh inch; that is, as the ſecant is to the radius of the triangle, provided the tracer draws lines at right angles to the ſide of the plate; but if the traced lines be at right angles to the line to be divided, then the diviſions on that line will be ſhorter than they would be on a parallel line of the plate, and in the proportion of the co-ſine of the angle of inclination to radius. In order to adjuſt the inclination of a ruler laid on the plate A, two ſectoral portions of a circle are laid down on one of its ends, with an extent from the point J, near the fixing ſcrews on the edge of this plate. The outer ſector is divided into proper degrees, and is numbered from 1 to 9, which degrees are ſubdivided into 6, or 10 minutes ſpaces; but the inner ſector is divided into the proportion of the coſines to radius 10,000, and its diviſions are numbered 10, 20, 30, &c. to 140. The uſe of this contrivance will be beſt underſtood by an example: for inſtance, if a line of $9\frac{999}{1000}$ were to be divided into the ſame number of diviſions, and in the ſame manner as if it were 10 inches long exactly; put the ruler to be divided to the cutting frame, hereafter deſcribed, and turn the handle, T, that moves the apparatus, till the ſame edge of the ruler cuts the central point J, and the firſt diviſion from the O of the inner ſector; then ſcrew the ruler faſt to the plate A, and when it has moved ten inches in its own direction, the whole length of the diviſions on the line divided will be only $9\frac{999}{1000}$ inches, though the divided ſpaces will be reſpectively equal among themſelves. It is not neceſſary for us to particularize the precautions taken, in making all the ſpaces of the teeth ratched equal to each other, during the act of ratching, which was done with a notched ſcrew: this was done by means of points previouſly made and examined, with a wire at every 16 revolutions of the ſcrew, till the teeth were a little indented to guide the ſcrew along the whole line by continual revolutions, as was the caſe in the circular dividing inſtrument, more particularly deſcribed, becauſe found more particularly uſeful. B, in *fig.* 1, is a ſtrong iron frame, 48 inches long, having two edges, *a* and *b*, riſing half an inch above its ſurface; theſe two edges are made very ſtraight, and are in the ſame plane; the inſide of the edge *a* is alſo made as ſtraight as poſſible. The plate, A, ſlides on the two edges of the iron frame; beneath it are two ſprings, *c*, *c*, ſeen in *fig.* 3, each faſtened at the extreme ends to the plate A, by the ſcrews, *s*, *s*; at the other end of each ſpring is a roller, *e*, of tempered ſteel, turning on an axis in theſe ſprings; there is alſo a third roller, *d*, of tempered ſteel, let into the iron frame, not ſeen, near where the threads of the endleſs ſcrew act; this roller has a long axis, ſo ſituated that it may be raiſed or depreſſed as occaſion may require, to bear the weight of the plate A, and rule or inſtrument placed on it. C, in *figs.* 1 and 2, is the endleſs ſcrew of tempered ſteel, with pivots of two fruſta of inverted cones, ſimilar to thoſe deſcribed in the engine for dividing circles, &c. which turn in adjuſtable half holes in braſs cocks ſcrewed to the iron frame. G, G, in *fig.* 3, are two ſmall ſteel frames turning on centres, *k*, faſtened to the underſide of the plate A, and equidiſtant from the edge of it; in each frame is a roller, *y*, of tempered ſteel, turning very concentric with their pivots, and exactly of the ſame diameter. The two ſmall frames are connected together by the long braſs bar E, which turns on a ſtud in each frame, and which preſerves its paralleliſm, on the principle of a common parallel ruler. This apparatus ſerves to preſs the edge of the plate, A, with a motion parallel to itſelf againſt the threads of the endleſs ſcrew. On the end of the plate, A, is a ſpring of tempered ſteel, acting as a bent lever. The ſpring end of this lever has a ketch which paſſes under the head of the ſtud *l*, that is on the end of the connecting piece E. While the other end of the lever is preſſed gradually down towards the plate A, by turning the finger-ſcrew F, the connecting piece, E, is drawn forward, ſo that the ſteel rollers, borne by the ſprings T, in *fig.* 3, preſſing againſt the edge, *a*, of the iron frame, in *fig.* 1, may force the ſide of the plate againſt the endleſs ſcrew.

Beſides the micrometer head, already named, the arbor of the dividing ſcrew, which has its threads ſimilar to thoſe of the notched ratching ſcrew, has at its oppoſite end two ſets of ratched wheels; one ſet for turning the ſcrew, and the other ſet for ſtopping it at the proper times. Theſe ſets are each compoſed of three wheels, of which one has 32 teeth, another 48, and the third 50, which afford the means of ſubdividing the inch into ſpaces of different denominations; thoſe wheels uſed in ſtopping the ſcrew are ratched, with the teeth pointing in a contrary direction to

those of the wheels for putting it in motion. I represents a cylinder of brass, having on one end two steel rings, *a* and *b*, with their contiguous edges cut into ratched teeth, in contrary directions, so as to fit each other as seen in the figure; on one of these rings is an index, and the other has its teeth numbered 10, 20, &c. up to 50; the other end of the cylinder is made hollow, and contains one of the sets of ratched wheels, already named. There are two slits opposite each other, pierced through the hollow part of the cylinder W; in each of which slits is a click turning on an axis, and pressed into the teeth of the ratched wheel by a small spring; these clicks may be moved along their axis, so as to catch in any one of the three ratched wheels, and may be fastened at that place by a small tightening screw *s*. The cylinder I, with the clicks, &c. turns on a steel axis, attached to the piece K, in a line with the axis of the endless screw. Motion is given to this cylinder round its axis by a piece of catgut, which hath one end fastened to the ratched ring *b*; and the other end, after passing four or five times round the cylinder, is fastened to a treadle, and, on pressing the treadle down, the clicks, *s*, catch in the teeth of one of the ratched wheels; by which contrivance the cylinder I, together with the endless screw, is turned round its axis, and its motion carries the plate, A, along the iron frame, and at the same time winds up the spiral spring *u*; but on releasing the treadle, the said spring unbends itself, the clicks quit the ratched wheel, and leave the endless screw at rest, whilst the cylinder, I, turns in an opposite direction, and raises the treadle to its former situation. V, in *fig.* 2, is a small square bar of steel, having both its extremities cylindrical; these cylinders move in holes lined with hardened steel, one in the piece D, and the other in the piece K. This bar carries three different pieces, which are of tempered steel; the middle one, *t*, is made to lie in the interval between the threads of the screw cut on the cylinder, and passes nearly half round its circumference: it is kept in the threads by a spring, *e*, that presses on a piece, *q*, screwed to the iron frame; this piece being attached to the bar, V, by a screw, turning the cylinder, I, on its axis, will give a longitudinal motion to the bar V. The upper end of the piece *f*, *fig.* 2, is formed into a hook, and may be set to catch in the teeth of any of the ratchet wheels, and then be fastened to the bar, V, by a screw *i*; towards the other end of the bar is a piece *j*, which serves to stop the cylinder in turning back, so as to limit the number of revolutions and parts of a revolution required, and is fastened to any required place on the bar, V, by the finger-screw *s*.

When the engine is used, the treadle is pressed down, and the catgut turns the cylinder I; in the mean time, the piece, *t*, moves along the thread till a stud, *r*, on the cylinder, striking on the top of the curved piece *t*, bends the spring *e*, until that piece rests on the piece *q*; by bending this spring, the square bar is turned a little on its axis, and pulls the hook, *f*, into the teeth on the ratched wheel R: then the treadle being released, the spiral spring turns back the cylinder till the piece, *j*, is brought under the stop on the ratchet ring *b*. The parts of a revolution are regulated by setting the number required on the ratchet ring, *b*, to the index on the fixed ring *a*; each of the teeth answers to the motion of $\frac{1}{2160}$th of an inch of the plate A; and the number of revolutions, each of which moves the plate, A, $\frac{1}{72}$ths of an inch, is regulated by setting the piece, *j*, on the bar. I, in *fig.* 1, represents the steel frame in which the tracer is fixed; this frame turns between the conical points of two screws, *n*, *n*, of tempered steel, which are screwed in the frame Q, *fig.* 2; there are also two similar screws in the same frame Q, at *m*, *m*; the points of these screws, which are also of tempered steel, turn in conical holes in the piece P; by means of this parallel motion, the tracing point, by which the dividing lines are cut, will always describe the same line without any lateral bending; the tracer is put on the hole in the axis *b*, *fig.* 1, and is fixed there by the four tightening screws, *f*, that press the holding piece, *c*, against the flattened part of the axis of motion. This small axis, which has its pivots formed of double cones, turns between half holes, and may be fixed when the tracer is set to any required inclination, by tightening the screws of pressure, *s*, *s*, *s*, *s*. Besides these parts of the engine, there is a brass ruler made as an appendage for setting the line to be divided in its true situation, but is not necessary to be particularly described: this ruler may be set parallel to the edge of the plate A, or to any angle of inclination, by turning the handle T, which moves the piece P, with the cutting frame and ruler, on the centre *x*; and the required position may be rendered permanent by tightening the capstan screw *p*.

Engine-*Shaft*, in *Mining*, is generally applied to the shaft or well wherein the pumps are erected for freeing a mine of its water; but in districts where the mines are relieved of water by soughs, as in the mountainous part of Derbyshire, it is common to find the shafts at which they draw ore by a horse-gin, called the engine-shaft, and the gin itself an engine.

Engine *to drive Fuzes*, in *Gunnery*, consists of a wheel with a handle to it, to raise a certain weight, and to let it fall upon the driver, by which the strokes become more equal.

Engine *to draw Fuzes* has a screw fixed upon a three-legged stand, the bottom of which has a ring to place it upon the shell; and at the end of the screw is fixed a hand-screw, by means of a collar, which, being screwed on the fuze, by turning the upper screw, draws out or raises the fuze.

ENGINEER, or Ingineer, in its general sense, is applied to a contriver or maker of any kind of useful engines or machines.

In its more proper sense, it denotes an officer in an army or fortified place, whose business it is to contrive and inspect attacks, defences, works, &c. The term engineer is said to be of modern date, and to have been first used in the year 1650, when one Cap. Thomas Rudd had the title of chief engineer to the king. In 1634 an engineer was called camp-master general, and sometimes engine-master, being always subordinate to the master of the ordnance.

An engineer should be an able and expert mathematician, particularly versed in military architecture and gunnery; being often sent to view and examine the places intended to be attacked; to choose out and shew the general the weakest place; to draw the trenches, assign the places of arms, galleries, lodgments on the counterscarp and half-moons; conduct the works, saps, mines, &c. and appoint the workmen their nightly task; he is also to make the lines of contravallation; with the redoubts, &c.

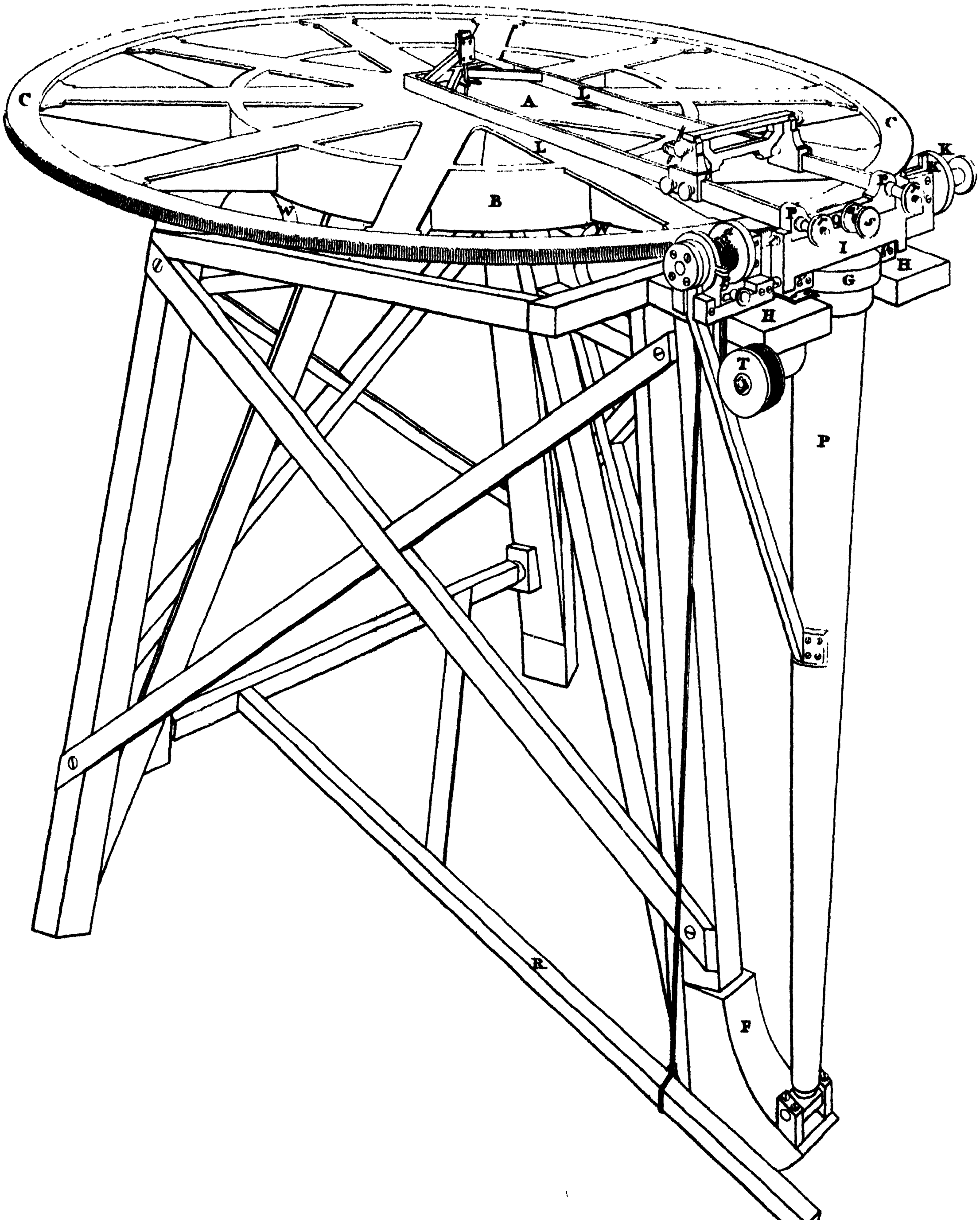
Under the establishment of the office of his majesty's ordnance in England, the corps of *royal engineers* consists of one colonel in chief, one colonel in second, three colonels commandant, six colonels, 12 lieutenant-colonels, 27 captains, 28 second-captains, 55 first-lieutenants, 28 second-lieutenants, an inspector-general of fortifications, his deputy brigade-major, adjutant, and quarter-master.

The establishment of the corps of *invalid engineers* comprehends a colonel, lieutenant-colonel, captain, captain-lieutenant and captain, first-lieutenant and second-lieutenant.

The corps of *royal engineers* in Ireland confifts of a director, colonel, lieutenant-colonel, major, captain, captain-lieutenant, and captain, and two firft-lieutenants. See Ordnance.

Engineers, *Civil*, a denomination which comprifes an order or profeffion of perfons highly refpectable for their talents and fcientific attainments, and eminently ufeful under this appellation, as the canals, docks, harbours, light houfes, &c. amply and honourably teftify. This order of artifts is faid to have commenced in this country about the year 1760, at which period the advancement of the arts and fciences was fingularly rapid. In 1771, Mr. Smeaton, fo well known in this department of fcience, projected and eftablifhed an affociation, or fociety of engineers. During an interval of 20 years, the number of members of this fociety increafed to 65, of whom 15 were real engineers, and the refidue being compofed either of amateurs, or of ingenious workmen and artificers. In May 1792 this fociety was diffolved in confequence of an unpleafant circumftance, which had interrupted its harmony; but a renewal of it, under a better form, was foon intended, though not accomplifhed during the life-time of Mr. Smeaton. His death happened in October 1792, and the firft meeting of the new inftitution, entitled "The Society of Civil Engineers," was held on April 15, 1793, by Mr. Jeffop, Mr. Mylne, Mr. Rennie, and Mr. Whitworth. According to the new conftitution of the fociety, it is divided into three claffes. The firft clafs, as ordinary members, confifts of real engineers. The fecond clafs, as honorary members, is compofed of men of fcience, and gentlemen of rank and fortune, who have attended to the fubject of civil engineering. The third clafs, as honorary members alfo, confifts of artifts, whofe profeffions and employments are connected with what is called civil engineering. The meetings are held at the Crown and Anchor, in the Strand, every other Friday, during the feffion of parliament. See Reports of the late Mr. John Smeaton, F.R.S. &c. vol. i. 4to. 1797.

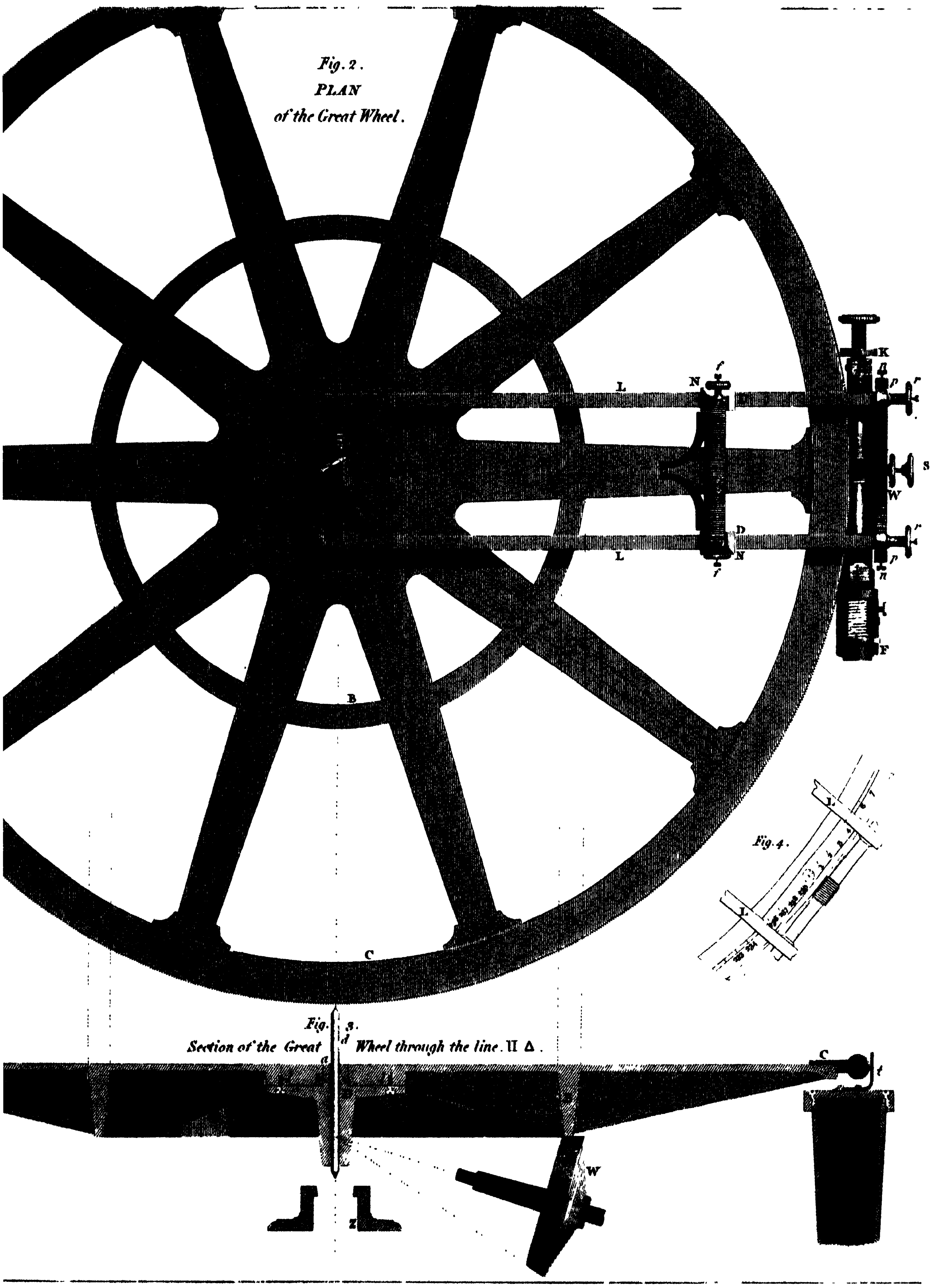
A perspective View of Mr. RAMSDEN'S dividing Engine.



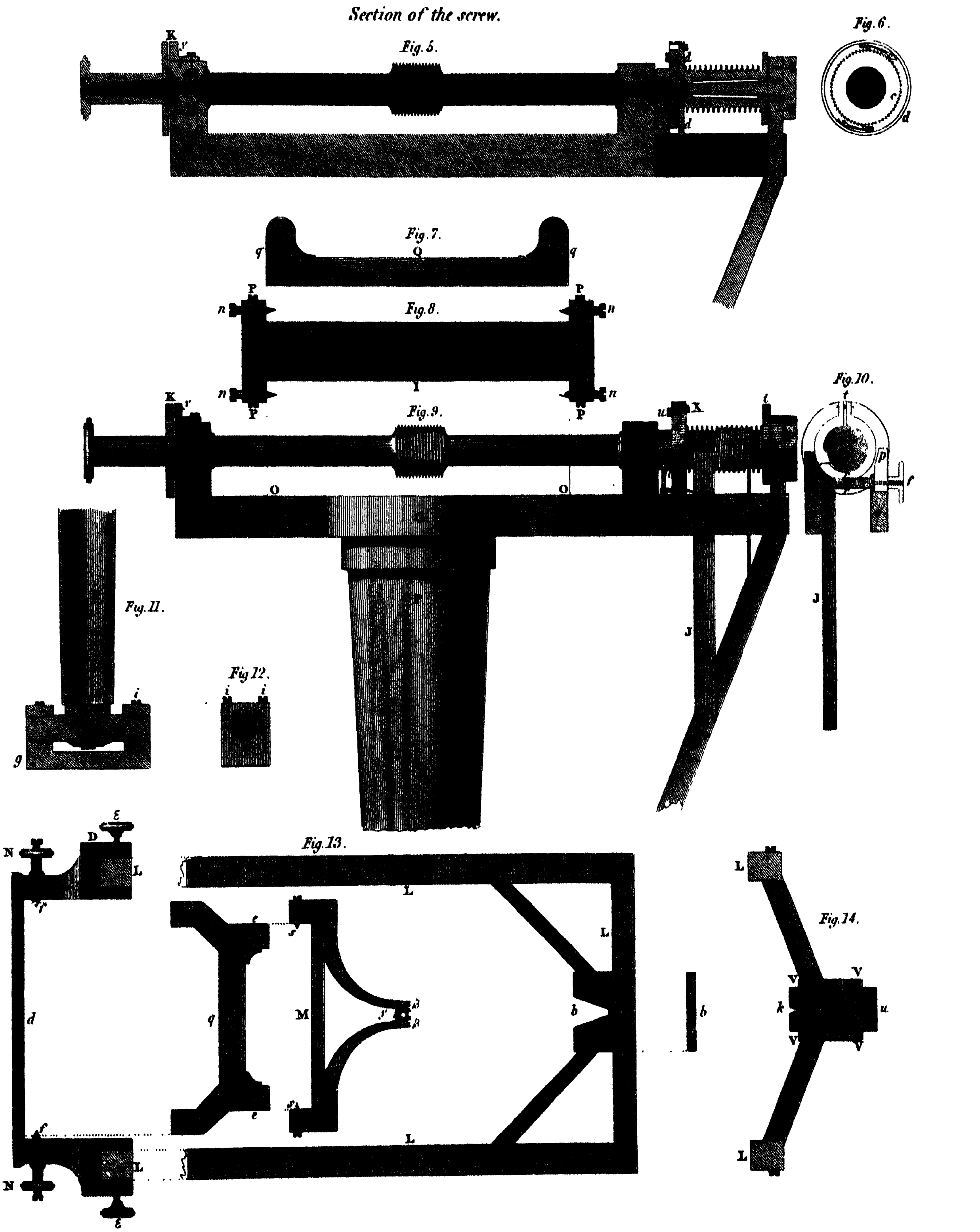
Published as the Act directs, &c. by Longman, Hurst, Rees and Orme, Paternoster Row.

Engraved by Wilson Lowry.

Mr. RAMSDEN'S DIVIDING ENGINE.

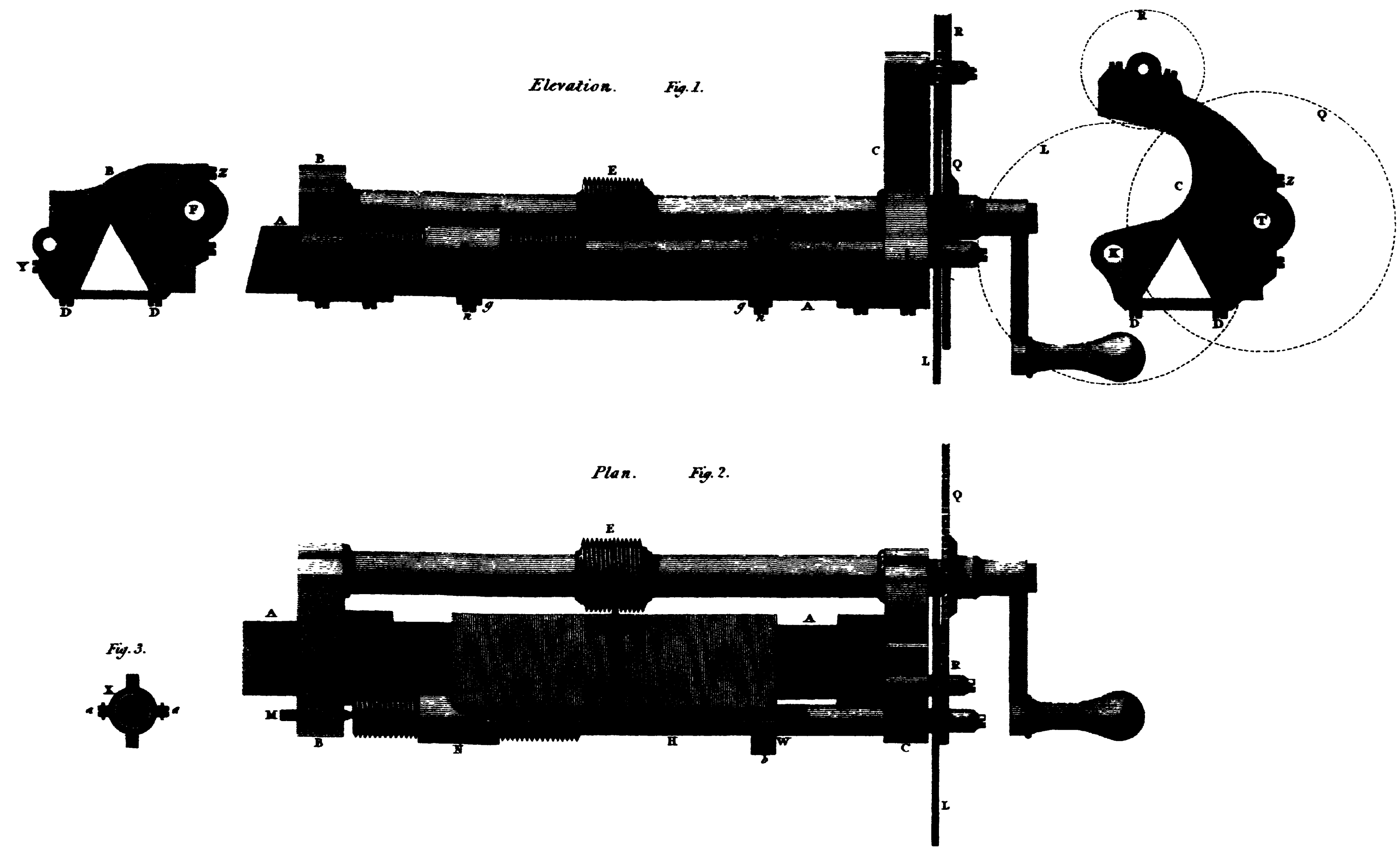


M.r RAMSDENS DIVIDING ENGINE.



Published as the Act directs, 1809, by Longman, Hurst, Rees & Orme, Paternoster Row
Engraved by Wilson Lowry.

Engine for cutting the Screw of Ramsden's Circular Dividing Engine.



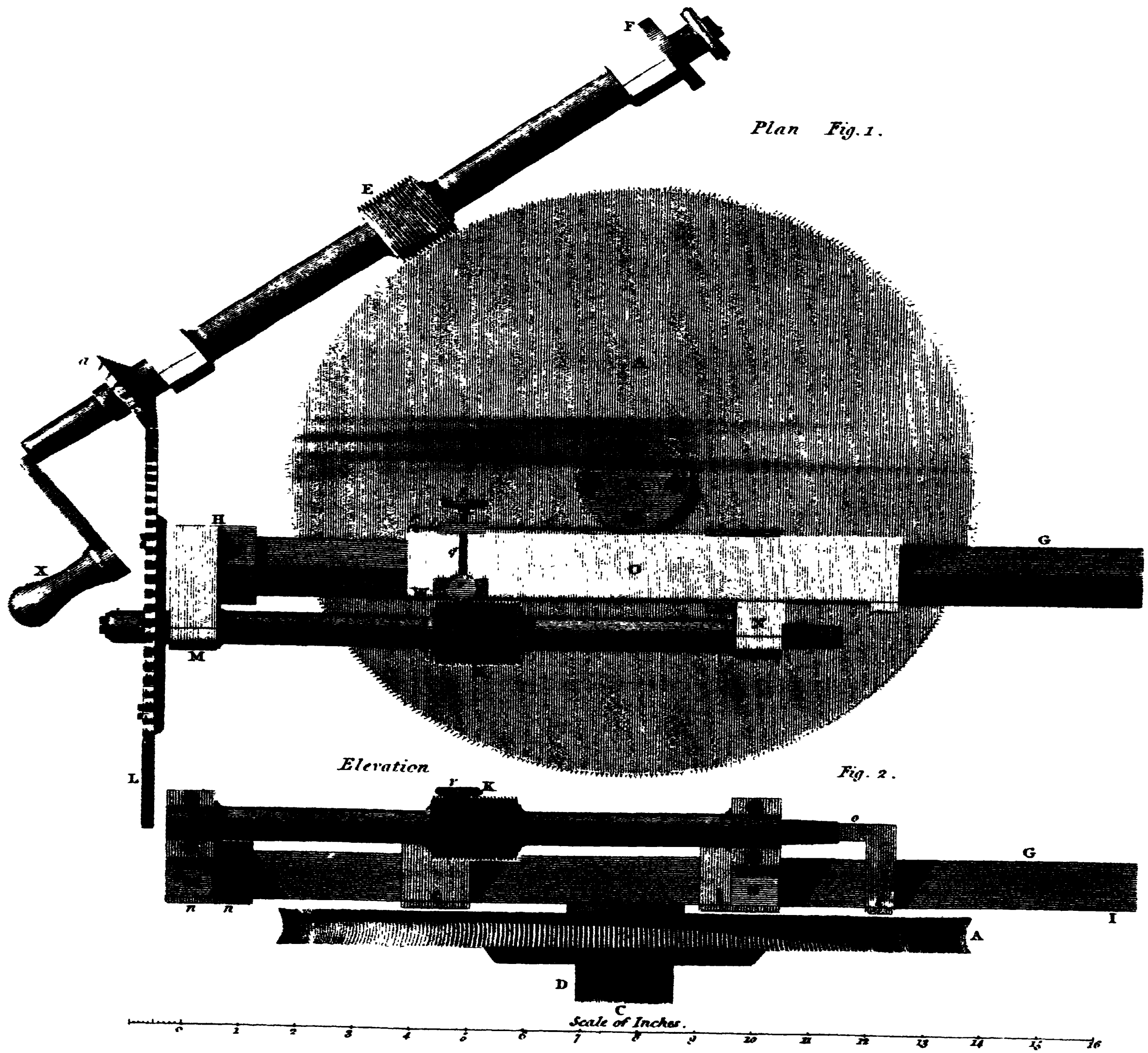
Drawn by J. Farey.

Published as the Act directs 1812, by Longman, Hurst Rees Orme and Brown, Paternoster Row, London.

Engraved by W. Lowry.

ENGINES.

ENGINE for cutting the Screw of RAMSDENS Straight Line dividing Engi



Drawn by J.

Published as the Act directs, 1811. by Longman, Hurst, Rees, Orme & Brown, Paternoster Row.

Engrav

RAMSDEN'S ENGINE *for dividing Straight Lines.*

Fig. 3.

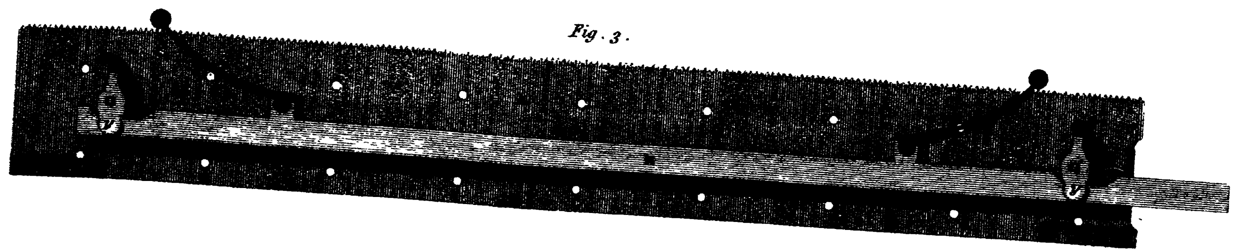


Fig. 1.

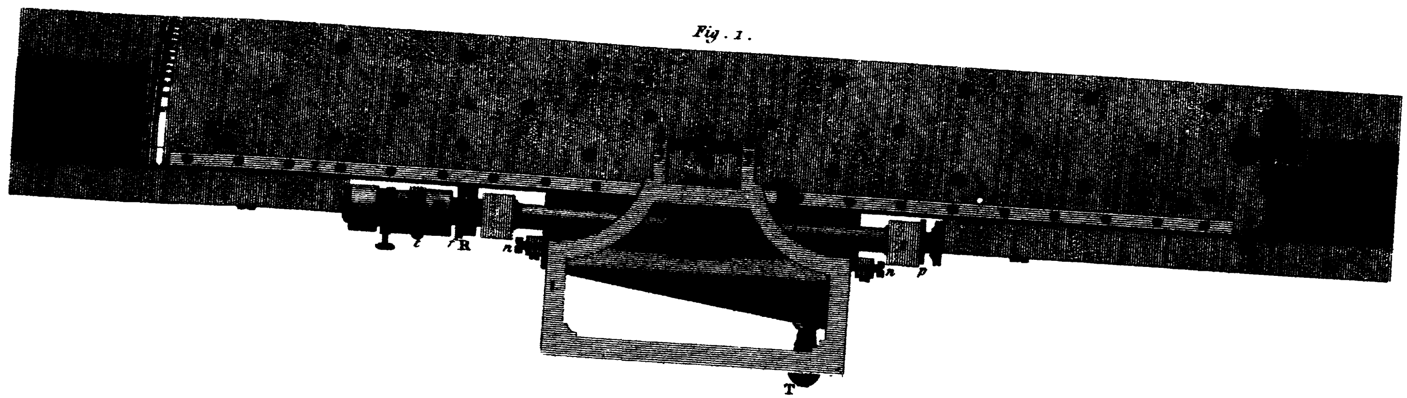
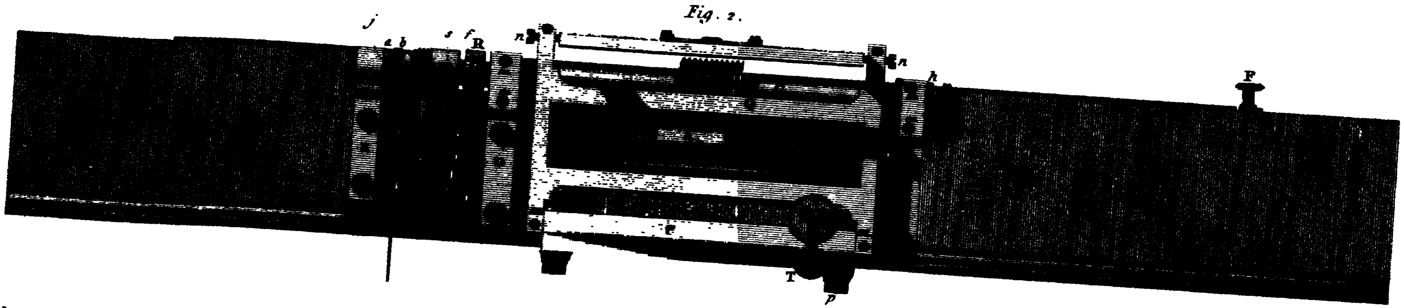


Fig. 2.



J. Farey Jun. del.

Published as the Act directs, 1811 by Longman, Hurst, Rees, Orme & Brown, Paternoster Row.

Engraved by Wilson Lowry.

Ether

ETHER, in *Chemistry*, is a light, odorant, inflammable liquid, produced by the action of certain of the acids upon alcohol. The acids that have actually been employed for this purpose are the sulphuric, the nitric, the muriatic, the acetic, and the fluoric; whence originate as many species, or perhaps varieties of ether, all of which we shall describe in due order.

§ 1. *Sulphuric ether.*—The method of preparing this substance is first mentioned in the Dispensatory of Valerius Cordus, published about the year 1540; it was also known to Basil Valentine, Paracelsus, and Boyle: it had, however, attracted the notice of chemists only in a very imperfect degree, before it was described by Froben, a German, in the

Philosophical Transactions for 1730. Since that period the preparation and properties of sulphuric ether have been carefully investigated by many able chemists, especially Scheele, Dollfuss, Macquer, Pelletier, Vauquelin and Fourcroy.

The mode of obtaining ether in the small way is as follows. Take a tubulated glass retort, of the capacity of about six quarts, lengthen its beak by an adopter, and pass the other end of the adopter into a two-neck quilled balloon receiver; fix another adopter into the opposite neck of the balloon, and join to this a common quilled balloon receiver, placed in such a position that the quill, instead of pointing directly downwards, as in the first receiver, shall slant gently upwards; then lute all the junctures with linseed meal or common paste, except that of the retort to the first adopter; fix also a 24 ounce vial to the quill of the first receiver, and loosely close the quill of the second with a cork or plug of moist paper. The lute being moderately dry and hard, withdraw the retort, and pour in through the tubulure 40 ounces by weight of rectified alcohol, and 32 ounces of the strongest sulphuric acid. Replace the retort with its contents, being careful to shake it as little as possible, and let it remain for 12 hours or more, during which the acid and alcohol will gradually act on each other, producing a considerable degree of heat. Afterwards withdraw the retort, and mix together its contents as accurately as possible, by communicating to them a gentle circular motion; this being finished, replace the retort, and carefully close by lute its junction with the adopter, and leave the whole in this state till the contents of the retort have acquired a reddish-brown colour, which will take place in a day or two. Now proceed to distillation, by placing a pot of lighted charcoal beneath the retort, observing to heat it very gradually. The first impression of the fire drives off a little highly dephlegmated alcohol, but as soon as the mixture begins to boil, the ether itself passes over and condenses on the sides of the receiver in large streaks. It is now essentially requisite to keep the receiver as cool as possible, by the application of ice or of wet cloths wrung out in cold water and frequently renewed; and if this is properly attended to, by far the greater part of the ether will be condensed in the first receiver, whence it will flow into the vial beneath; a little, however, will pass through the second adopter into the second receiver, where it must be condensed by the same means as have already been recommended. The contents of the retort are to be kept moderately boiling, till sulphurous acid gas begins to pass through the quill of the second receiver, which may be known at once by its strong suffocating odour. As soon as this is perceived, the fire is to be withdrawn, and the vial is to be detached from the receiver, and its contents poured into a ground-stoppered bottle; being then replaced as before, the process of distillation is to be re-commenced till about six or seven ounces of a coloured liquid are produced, after which the operation is to be stopped. The original mixture of sulphuric acid and alcohol is thus divided into three separate products; namely, the residue in the retort, and the products of the second and first distillations. In the retort is a black thickish matter, smelling strongly of sulphurous and acetous acids, and intensely sour to the taste. If diluted with an equal bulk of warm water and filtered through pounded glass or clean white sand, it will be separated from the carbonaceous matter with which it was loaded, and by subsequent boiling the sulphurous and acetous acids will be driven off, leaving behind sulphuric acid in a considerable degree of concentration, and applicable to a variety of useful purposes. The product of the second distillation consists of two distinct liquids, the heaviest of which is acidulous water, and the lighter an impure ether, called *oil of wine*, which may be separated from the water by inverting the vial that contains them in warm water; a little of the ether is in consequence converted into elastic vapour, which forces out of the vial the lower and heavier fluid. The product of the first distillation is impure ether, in quantity about 17½ ounces. Thus from 32 ounces of sulphuric acid and 40 ounces of alcohol there are procured about 17½ ounces of impure ether, and three ounces of oil of wine; and the sulphuric acid that may be recovered, taking into consideration its quantity and density, amounts to about 46 per cent. of that originally employed.

Ether, when fresh distilled, is contaminated by sulphurous and acetous acids and a little coloured oil, in consequence of which it is necessary to purify it by rectification. This is generally done by adding to the ether successive portions of caustic potash or soda dissolved in water, and shaking together the two fluids in a well closed bottle, after each addition of alkali, till the sulphurous odour is totally destroyed; the contents of the bottle are then to be poured into a retort, and by the application of a gentle heat, never amounting to ebullition, the ether will pass into the receiver in a state of great purity, leaving behind a watery saline liquor covered by a thin film of brownish-yellow oil. Scheele recommends that the alkali employed in rectification should be dissolved in alcohol instead of water; the advantage of which is that no spontaneous separation of the liquors takes place, and therefore the sulphurous and acetous acids are neutralized and separated with greater certainty. Distillation at a gentle heat will readily separate the ether from the other ingredients. A still cheaper and very effectual method of rectifying ether is the following, first employed by Mr. Woulfe. "Fill three-fourths of a bottle with the impure ether, add a little water and a portion of slacked lime; agitate the bottle with violence, and keep it for some time in cold water, before taking out the cork; if the smell of the sulphurous acid be not removed, add a little more lime and agitate a second time. Decant off the ether into a receiver, and distil it off." Another very cheap and ingenious process was invented by Pelletier. It consists in adding to the impure ether a little finely pulverized black oxyd of manganese. The mixture being corked up in a bottle, is to be well shaken four or five times a day for the space of a week, at the end of which time the sulphurous acid will have been converted into sulphuric, and will have combined with the manganese, from which the ether may be poured off without the necessity of distillation.

By any of the above methods ether is rectified sufficiently for any purposes to which it is usually applied; but if the greatest possible degree of purity is required, there should be added to the rectified ether successive portions of dry pulverized muriat of lime, till it ceases to be dissolved; from this mixture, by distillation with a very gentle heat, and keeping at the same time the receiver quite cold by the application of ice, an ether may be procured, probably entirely free from alcohol and water, and of the specific gravity of 0.65.

Rectified ether exhibits the following properties. It is a transparent colourless liquor, of a peculiar and to most persons an agreeably fragrant odour, and a hot penetrating, and somewhat suffocating taste. Its usual specific gravity, according to Lavoisier, is $=0.758$. It is volatilizable at a lower temperature, and more rapidly than any other liquid, a considerable proportion being lost, especially in hot weather, by merely pouring it from one vial into another; hence the vessels in which it is kept ought to be very exactly closed, and for further security are often kept inverted in cold

water. It boils at 98° Fahr. under the usual atmospherical pressure, and at 20° in vacuo.

Owing to the extraordinary rapidity with which ether evaporates, it possesses a very great power of refrigeration. This is made obvious to the feeling by pouring a little into the palm of the hand; it is almost instantly volatilized, and the hand becomes painfully cold. So also if some fine tow is wrapped about the bulb of a small thermometer, and the blast from a pair of double bellows is let upon it, after it has been well soaked in ether, the mercury in the thermometer will, in the space of a minute or less, be lowered to 0° Fahr. Ether, notwithstanding its ready volatility, is capable of being congealed at a low temperature. If a small matrass filled with this fluid is cooled down to −25° Fahr. by a mixture of snow and muriat of lime, the liquor becomes gradually filled with brilliant transparent crystalline laminæ, resembling benzoic acid or oxymuriat of potash; and presently, especially at a somewhat lower temperature, the whole is congealed into a white almost inodorous mass. Ether is remarkably inflammable, taking fire instantly on the near approach of an ignited body; it burns with a large white flame and a little smoke, and is resolved into water, carbonic acid, and a minute quantity of charcoal. When passed through a red-hot earthenware tube, it is entirely decomposed, and a large production of carburetted hydrogen takes place. Ether remarkably increases the bulk of any of the permanent gasses to which it was added, as was first observed by Dr. Priestley. A small quantity of this fluid being mixed with oxygen confined over mercury, exactly doubled its bulk, nor could any additional quantity occasion a further dilatation. Nearly the same effect took place with atmospheric air, azot, hydrogen, nitrous gas, and carbonic acid; but by a slight agitation in water the ether was absorbed, and the gas resumed its former dimensions without any alteration of its original properties. If oxygen gas thus diluted by ether is set fire to, it burns rapidly, but does not explode; but if one part of this mixture is added to three parts of oxygen, the application of an ignited body, or of the electric spark, causes a violent explosion, the products of which are water and 2½ parts of carbonic acid. Hence it appears that one part of ether requires 6.8 of oxygen for its saturation, and that the proportion of carbon to hydrogen in sulphuric ether is nearly as 5 to 1.

Water and ether appear to combine with each other in two different proportions. If equal parts of these fluids are shaken together in a graduated tube, the ether will be found to have diminished in bulk about $\frac{2}{10}$, and the water to have enlarged in nearly the same proportion; the lower fluid consists of water saturated with ether, and the upper fluid is ether combined with a little water. The ether in this state is said to be *washed*, and acquires in consequence some properties which pure ether does not possess; in particular, it is now capable of dissolving caoutchouc with great ease, whereas this substance is acted on by pure ether only in a very imperfect manner. Phosphorus is soluble in ether, but the solution is not luminous. When ether is boiled with phosphorus, it often deposits crystals by cooling; agitation with water produces no change in this liquid, but the addition of a little alcohol causes an immediate turbidness, whence the sophistication of ether by alcohol may be detected by the addition of a few drops of phosphorized ether. The fixed alkalies seem incapable of uniting with ether, but ammoniacal gas is absorbed by it very copiously. The same may be observed of nitrous gas; but neither of these combinations has hitherto been submitted to an accurate examination. Sulphuric acid acts on ether with considerable energy, especially if assisted by a gentle heat; it is converted into a brownish oily fluid, much heavier than ether, called oil of wine, and at a higher temperature is changed into olefiant gas. With regard to the action of oxymuriatic acid on ether, a curious experiment is related by Mr. Cruickshank. "If we fill a bottle of the capacity of three or four pints with the pure oxymuriatic acid gas, taking care to expel the water as completely as possible, and then throw into it about a drachm or half a drachm of good ether, covering its mouth immediately with a piece of light wood or paper, in a few seconds white vapour will be perceived, moving circularly in the bottle; this will soon be followed by an explosion, accompanied by flame, at the same time a very considerable quantity of carbon will be deposited, and the bottle will be found to contain carbonic acid gas." Nitric acid excites a considerable effervescence in ether, and seems to convert it into oil of wine. The essential oils are soluble in ether, and it combines with alcohol in almost all proportions.

Concerning the theory of etherification, much has been written, and many experiments have been made by able chemists, without, however, obtaining the satisfaction that could be wished. According to Macquer, ether is a substance intermediate between alcohol and oil, and alcohol approaches to the state of oil precisely in proportion as it parts with its water of composition. But though it is true that the production of water accompanies the conversion of alchohol into ether, and of ether into oil of wine, yet this is by no means the only phenomenon, so that the theory of Macquer is, at best, imperfect, since the deposition of charcoal, and the generation of acetous acid, are not at all accounted for. According to Pelletier, Chaptal, and others, the whole process of etherification consists in a transfer of oxygen from the sulphuric acid to the alcohol: the disengagement of sulphurous acid accompanies the production of ether, and therefore shews that the sulphuric acid is deoxygenated: the oxygen, thus separated, does not come over in the state of gas, and therefore must be combined with the alcohol forming ether. But in reply, it may be observed, that this mode of explanation accounts for only a few of the phenomena, and that the preparation of ether, if carefully managed, may be carried on without the disengagement of any sulphurous acid. The most elaborate enquiry into this intricate subject was undertaken by Vauquelin and Fourcroy, which we shall now proceed to detail, though it is by no means so complete and satisfactory as to preclude the necessity of further researches. The facts and observations by which this theory is supported are the following.

If one part of alcohol and two of sulphuric acid are mixed together, the temperature rises to about 200° Fahr.; the mass immediately acquires a deep brownish-red colour, which deepens into black in a few days after, and at the same time exhales a vapour manifestly ethereous.

Equal parts of concentrated sulphuric acid and rectified alcohol acquire on mixture a temperature of 190° Fahr.; bubbles of gas are extricated, the liquor becomes turbid and opalescent, and at the end of a few days acquires a deep red colour. The whole being then transferred to a distillatory pneumatic apparatus, and being heated to 107° Fahr., ebullition takes place, and ether passes over into the recipient; if the operation is carefully conducted no elastic fluid is disengaged, and the vapour, when condensed, is found to be only water and ether. When the liquor thus obtained amounts to about half of the alcohol employed, sulphurous acid begins to be manifest, and, in a short time, the production of ether ceases, and is succeeded by oil of wine, accompanied by acetous acid. The contents of the retort being kept boiling, and becoming more and more concentrated as

the distillation proceeds, are constantly acquiring a higher temperature; when this amounts to about 234° Fahr., olefiant gas begins to come over, and continues till the oil of wine ceases to flow. At this period carbonic acid gas first makes its appearance, and water and sulphurous acid still continue to be produced, the residue in the retort being in the mean time reduced to little else than sulphuric acid thickened by charcoal.

From these facts the able chemists who observed them have concluded,

1. That the spontaneous action of alcohol and sulphuric acid, when this latter is considerably in excess, is sufficient for the formation of ether without the assistance of any extraneous heat, and that by duly proportioning the two substances, the alcohol might be wholly decomposed and made to yield all the ether of which it is capable when treated in the usual manner.

2. That the formation of ether is not owing to the affinity of the oxygen of the sulphuric acid, for the hydrogen and carbon of the alcohol, because in the preparation of ether no sulphurous acid gas is evolved till the production of ether has almost ceased. It must therefore be the entire attraction of the acid for one or more of the elements of the alcohol that determines its decomposition: now since water is formed during the whole process, and, since the attraction of sulphuric acid for this substance is very powerful, it appears likely that this is the cause that destroys the equilibrium of the affinities by which the elementary particles of alcohol are retained in combination, and induces the oxygen and hydrogen to unite and form water. Hence it might at first sight be supposed that ether differs from alcohol in containing a smaller proportion of oxygen and hydrogen. This however will not be found to be the case, when we advert to the deposition of charcoal, which, equally with the production of water, accompanies the formation of ether: now the amount of charcoal deposited is greater in proportion to that which is left, than the hydrogen of the water compared to what remains in the ether; therefore this latter fluid, though composed of the same elements as alcohol, differs from it in containing a smaller proportion of carbon compared with the hydrogen. During the progress of distillation the heat to which the materials in the retort are exposed is constantly increasing, and (the affinity of the acid and alcohol also augmenting) the acid itself is at length decomposed, sulphurous acid is generated, and the excess of oxygen deprives the alcohol of part of its hydrogen whence results the oil of wine, differing from ether in containing a larger proportion of carbon; and in confirmation of this, it may be observed, that the charcoal deposited during the production of oil of wine is not so abundant as during the generation of ether.

Hence as (according to the authors of the above hypothesis) no decomposition of the sulphuric acid takes place during the formation of ether, the agency of the acid is partly that of detaining the alcohol in a temperature more than sufficient for the volatilization of this fluid when uncombined, and partly that of assisting the caloric to decompose the alcohol in consequence of its own powerful affinity for water.

A circumstance, however, first remarked by Scheele, but which has hitherto failed to obtain the notice to which it is so well entitled, sufficiently proves that in the formation of ether the acid employed acts a much more important part than is assigned to it in the theory of Vauquelin and Fourcroy. The admirable chemist above-mentioned states that if sulphuric ether be duly rectified by agitation with caustic alkali and subsequent distillation, it occasions no precipitate with barytic salts; but if to the ether thus purified there be added nitric acid, a copious precipitate is then produced by any of the soluble salts of barytes, indicating the presence of sulphuric acid. This fact strikingly points out that a portion of the base of the acid in a more or less deoxygenated state actually combines with the alcohol to compose ether. A like fact respecting muriatic ether is also mentioned by Scheele, namely, that though this ether, when rectified, occasions no decomposition of nitrated silver, yet the watery residue, after combustion of the ether, occasions a copious precipitate of muriated silver when mixed with the nitrat of this metal.

§ 2. *Nitrous ether.*—Although nitrous ether appears to have been known to Basil Valentine and Kunkel, yet the mode of its preparation being kept a secret, it soon ceased to be attended to by chemists, till in the year 1740 it was re-discovered by Duhamel, and afterwards was more particularly described by Navier, Sebastiani and others. It was prepared by Navier in the following manner. Put 12 ounces of rectified alcohol into a strong bottle, and add to it gradually and at intervals 8 ounces of strong nitric acid; after each portion of acid the liquors are to be well mixed by agitation, and the bottle is to be kept close corked and immersed up to its neck in ice and water; when the whole of the acid has been added, the bottle is to be well corked and further secured by a leathern cap. A stratum of ether rises by degrees to the surface of the liquor, and after five or six days the cork is to be pierced by a needle in order to let out the nitrous gas formed during the process: this gas having escaped, the cork is to be drawn, and the whole contents of the bottle being poured into a separatory funnel, the ether is thus procured unmixed with the heavier fluid on which it floats. This is, however, a very rude way of proceeding, and is attended with the utmost risk to the apparatus, the ether obtained also is in small quantity, and very impure. In order to prevent the violent and rapid action of the concentrated acid on the alcohol, which is the chief difficulty in the preparation of nitrous ether, Dr. Black proposed to interpose a thin stratum of pure water, and Fischer on the same principle made use of a little weak spirit of nitre for the same purpose. M. Dolfuss, from a careful repetition of the latter process, obtained the following result. Upon two ounces of very strong nitric acid he poured gently six drachms of the same very much diluted, and upon this three ounces of rectified alcohol. The bottle was loosely corked and suffered to stand undisturbed for three days; at this time the lower liquor appeared perfectly homogeneous with a stratum of ether floating above it. The whole being put into a retort and subjected to a gentle heat, there were obtained two ounces and a drachm of very pure ether unmixed with any acid, and the residue in the retort consisted of weak acetous acid mixed with oxalic acid, nearly the whole of the nitrous acid having been decomposed.

The last mode by which nitrous ether may be prepared, that we shall mention, and which on the whole appears to be the best, consists in mixing together alcohol and sulphuric acid, and pouring the liquor upon pulverized nitre; the sulphuric acid disengages the nitre, which immediately re-acts on the alcohol, and ether is the result. The able chemist whom we have already mentioned has shewn the excellence of this method by the following experiment. Having put into a retort four ounces of perfectly dry and pulverized nitre, he added to it a mixture consisting of two ounces of concentrated sulphuric acid, and four ounces of alcohol. The whole being submitted to distillation, there came over first six drachms of dulcified spirit of nitre, and then three ounces of a liquor from which by subsequent rectification were procured two ounces of pure ether.

Nitrous ether, when recently made, contains in loose combination a considerable quantity of nitrous gas, which in some degree modifies its properties, and renders it peculiarly liable to burst the bottles in which it is kept, especially in warm weather. This loss and trouble, however, may be avoided by rectifying the ether, which is best done in the following way. Pour into a strong vial so as to fill it two thirds, one part of ether and four parts of pump-water, and agitate it cautiously at first, frequently removing the thumb from the mouth of the vial in order to afford a free passage to the disengaged nitrous gas: when no more of this gas is given out add a quantity of dry pearlash equal in weight to the ether, and shake the whole well together; then put the mixture into a tubulated retort and proceed to distillation, taking care that the temperature does not exceed 120° Fahr.; the ether will pass into the receiver quite pure, and may be kept for any length of time in strong well closed bottles, with no more risk of accidents than sulphuric ether is subject to.

Nitrous ether resembles sulphuric ether in most of its properties; it has, however, a dilute yellow colour, and a somewhat different odour and flavour; this appears to be owing to the presence of a little resinous matter, from which it can never be entirely freed; by repeated distillations from fresh parcels of dry white sugar, as Deyeux has observed, this impurity may, in great part, be separated, and in proportion as this takes place the ether becomes more and more analogous to that prepared by sulphuric acid.

Nitrous ether appears capable of uniting with nitrous gas in two proportions; when the ether is in excess it forms nitrous ether in the state in which it appears previous to rectification; when the nitrous gas exceeds the ether it forms a permanently elastic fluid that has obtained the name of *etherized nitrous gas*. The preparation of this differs only in the rapidity with which the nitrous acid and alcohol are made to act on each other: when the combination takes place very slowly much ether and little etherized gas are the result, but when the contrary is the case, these two products are formed in an inverse proportion. If equal parts of alcohol and strong nitrous acid are mixed together at the common atmospheric temperature, or at a higher heat in proportion as the acid is diluted, a very rapid and copious effervescence takes place, a little ether is condensed in the receiver, and a large quantity of gas passes through the conducting tube, the first portions of which are etherized nitrous gas, and the latter common nitrous gas. What remains in the retort is acetic acid with a little oxalic acid. The properties of etherized nitrous gas (according to Van Diemen and his associates, to whom we are inbebted for its discovery) are the following. It has a disagreeable ethereal odour, exactly resembling that of olefiant gas when treated with oxymuriatic acid. By the application of flame it takes fire and burns with a yellowish lambent flame like alcohol; after the combustion has ceased, the vessel in which it was carried on contains a vapour of singular pungency. Water absorbs this gas, but requires a considerable time to effect this, except agitation is had recourse to, resembling, in this respect, carbonic acid. Alcohol produces the same effect as water, and takes up the gas not only more rapidly, but also in larger proportion. A solution of caustic potash also dissolves it, but with considerable difficulty, and on the addition of sulphuric or muriatic acids the etherized gas is again set at liberty unaltered in any of its properties. Ammonia, whether liquid or in the gaseous state, is incapable of contracting any union with it; the same is the case with oxygen gas at the common temperature, but a mixture of the two airs, when inflamed, produces a most violent explosion; sulphuric acid immediately decomposes this gas, by absorbing the ether, the nitrous gas retaining its elastic state. Sulphurous acid produces the same effect, only it requires some days for this purpose. If sulphuric acid, previously diluted with an equal weight of water, is placed in contact with this gas over mercury, its action is greatly retarded, the diminution of volume in the inclosed air takes place much more slowly, and even after some days a portion of ether is retained by the nitrous gas, which in consequence acquires the property of enlarging the flame of a taper that is immersed in it, in the same manner as nitrous oxyd does. Nitrous acid, according to the degree of its concentration, absorbs either wholly or in part, the ethereous portions of the gas, and the same may be observed of muriatic acid.

Etherized nitrous gas, when passed through a red-hot tube, deposits a little oil, and by subsequent washing in lime-water is freed from some carbonic acid; the residue is nitrous gas, mixed or combined with common carburetted hydrogen, and is not acted on by the sulphuric, nitric, or muriatic acids, by caustic potash or alcohol. The addition of oxygen gas produces red vapours, the nitrous gas is converted into acid, and the gaseous residue is carburetted hydrogen.

§ 3 *Muriatic ether.*—After chemists had shewn the production of ether by means of the sulphuric and nitric acids, it was natural to attempt its preparation by the muriatic acid. But this latter, in its usual state of dilution with water, has no action on alcohol, and therefore the various modes that were first practised to obtain muriatic ether entirely failed. A few chemists were said to have succeeded by employing simple muriatic acid, but in a more concentrated and dry state than the common liquid acid; the process, however, was both difficult and doubtful, and muriatic ether can hardly be said to have been known till Rouelle discovered that it might be prepared by distilling together alcohol and the smoking liquor of Libavius, which is a concentrated muriat of tin in its highest state of oxydation. The marquis de Courtanvaux, having repeated the process of Rouelle with great care, proposes the following as the best method of making the substance in question. Mix together in a retort three parts of the fuming muriat of tin and one of alcohol; a considerable degree of heat is immediately excited, and a white suffocating vapour arises, which, however, soon disappears on agitating the mixture. As soon as an ethereous odour is perceived, let two balloon receivers be luted on, and kept as cool as possible; then by the application of a gentle heat to the retort there comes over first a little dephlegmated alcohol, which is succeeded by the ether: by an increase of temperature a few drops of coloured oil are produced, and there arises, partly in the form of a soft butter and partly in that of a dense brown liquid, a quantity of smoking muriat of tin, part of the metallic oxyd remaining in the retort as a grey powder. When the ether thus procured is mixed with pearlash, a copious effervescence and precipitation take place, owing to the decomposition of some muriat of tin contained in the ether; after which, by distillation at a gentle heat, the ether arises in a state of great purity, amounting to half the impure product of the first distillation.

Several other of the metallic muriats have been found to be equally efficacious with the liquor of Libavius; the corrosive muriats of antimony and of arsenic, the muriats of bismuth and zinc, and the red muriat of iron, have in particular been used with success in the preparation of muriatic ether. Scheele.

Scheele, the discoverer of oxymuriatic acid, was induced to try the effect of this in the preparation of muriatic ether. For this purpose he put three ounces of alcohol into a

receiver, with which was connected a retort holding two ounces of common salt, upon which was poured an equal weight of sulphuric acid; the muriatic acid thus disengaged passed into the receiver, where it combined with the alcohol; and this, when saturated with acid, was transferred to another retort, containing three ounces of black oxyd of manganese in fine powder; the mixture instantly assumed a green colour, and presently after became so hot as to boil. When the ebullition had ceased, there was found in the receiver a liquor, from which, on mixture with water, a quantity of ether immediately separated. The same method is recommended by Van Mons, except that he employs only one fourth of the manganese used by Scheele, and performs the second distillation in a Woulfe's apparatus, the bottles of which contain a solution of caustic potash, by which the acid is prevented from re-acting on the ether.

Another mode of applying oxymuriatic acid to the preparation of ether, first practised by Scheele, is mentioned by Pelletier, and deserves to be repeated, as being perhaps the most expeditious and economical of any. He introduced into a large tubulated retort a mixture of eight ounces of manganese, and 16 ounces of decrepitated common salt, upon which he poured a mixture of 12 ounces of sulphuric acid, and eight ounces of alcohol. From this mass ten ounces were drawn off by distillation at a gentle heat, which, by subsequent rectification, yielded four ounces of ether.

It deserves to be remarked that the ether prepared by oxymuriatic acid generally deposits, during its rectification with potash, a considerable quantity of a clear aromatic and bitter oil, which sinks in drops to the bottom of the vessel; the ether also, according to Dollfuss, at least before rectification, is compleatly miscible with water when shaken with it for some time. The preparation of ether, by means of simple muriatic acid, is not easy, and was readily supposed to be impossible by some of the leaders of the modern school of French chemists, because it contradicted one of their early theories on the process of etherification; yet Beaumé, a chemist of great experience and unquestioned veracity, had affirmed, that he had obtained a small quantity of ether, by mixing together alcohol and muriatic acid, both of them in the state of vapour. The practicability of this method appears also to be established beyond doubt by the following formula of M. Basse. Keep a quantity of common salt in fusion for about an hour, in order to drive off all the water of crystallization, then pulverize it, and put 40 parts into a tubulated retort, connected with a Woulfe's apparatus, in the first bottle of which are to be poured 20 parts of most highly rectified alcohol; then add to the salt in the retort 20 parts of the strongest sulphuric acid, and proceed to distillation by a gentle heat, keeping the bottle holding the alcohol as cool as possible. When the alcohol is saturated with acid, transfer it to a retort, and distil over about one half of it; agitate this portion with an alkaline ley, and the ether will presently separate and float on the surface, whence it may be obtained by decantation or distillation. The quantity of ether from the above materials amounts to about five parts.

Muriatic ether has a striking resemblance to that prepared by sulphuric acid; its specific gravity, however, is greater, amounting, according to Hermbstadt, to 0.84; its taste also has a peculiar astringency like alum, and when burning it exhales a strong acrid odour, somewhat resembling that of sulphurous acid.

§ 4. *Fluoric ether.*—All that we know of this substance is derived from the discoveries of Scheele. He first impregnated rectified alcohol with fluoric acid gas, by distilling pulverized fluor spar with sulphuric acid, and placing alcohol in the receiver; the sm king spirit thus obtained was distilled with a gentle heat, but no sign of ether made its appearance. Another portion of the acidulated spirit was then mixed with black oxyd of manganese, and by subsequent distillation an ethereous fluid came over, from which, by subsequent rectification, a little ether was obtained of a very agreeable odour, resembling nitrous ether.

§ 5. *Acetic ether.*—Acetic ether was first discovered by the Count de Lauraguais; the method of its preparation was by distilling together equal parts of alcohol and acetic acid. Scheele, Porner, Bergman, and other chemists, repeated this process ineffectually, and hence were induced to suspect some error. In consequence of these doubts, Pelletier entered into a careful examination of the subject, and has both shewn the reason of the failure of Scheele, and has given the proper method by which to succeed. He distilled together equal parts of alcohol and acetic acid, and drew off a little more than half; this liquor was acidulous, and had an ethereal odour, but no true ether could be made to separate. He then mixed together 12 ounces of strong radical vinegar, and the same quantity of alcohol, and distilled over one half of it at a boiling temperature; this product he poured back into the retort and recommenced the distillation; the produce of this and of a third distillation were in like manner recohobated, and having distilled the whole again for the fourth time, he finally obtained 12 ounces of an ethereous fluid; with this he mixed a quantity of carbonated potash, sufficient to saturate the acid which it contained, and then submitted it to gentle distillation. The first six ounces that came over were pure acetous ether, the next four ounces also contained ether, but not so pure as the former. It is remarkable that during the cohobations a considerable absorption of air took place.

Scheele obtained acetous ether in a much more compendious manner, by mixing together acetat of potash, or of lead, or of copper, with alcohol, and then adding as much sulphuric acid as was requisite to decompose the acetous salt, and distilling the mixture at a low heat. The produce being shaken with water, the ether rises to the surface and may be poured off. From 16 parts acetat of lead, six parts strong sulphuric acid, and nine parts of water, Bucholz obtained six parts rectified ether.

Acetic ether always retains the odour of the acid by which it is formed; it is not so volatile as the ethers procured by the mineral acids; it burns with a lambent blue flame, like alcohol; it is soluble in a little more than twice its bulk of water, and is decomposable into acetous acid by repeated distillations at a very gentle heat.

Various other acids have been distilled with alcohol for the purpose of procuring ether, but with little or no success. Oxalic acid, with an equal weight of alcohol, yielded Bergman a watery somewhat etherized alcohol. Benzoic acid and alcohol, according to Scheele, afford no ether, but when a little common muriatic acid is added to the mixture, an ethereous liquor comes over, of which part floats on water and part sinks in the same fluid. The ether, or the lighter portion, has the odour of benzoic acid, burns with a clear flame and smoke, and is about equal in volatility to acetic ether. The phosphoric, boracic, tartarous, citric and succinic acids, were found by the same able chemist to be incapable of producing ether, either by their own action on alcohol, or when mixed with oxyd of manganese or muriatic acid.

Expanding Rigger

EXPANDING RIGGER, or *Drum*, in *Mechanics*, is a wheel, or rigger, to receive an endlefs rope; which can be enlarged or diminifhed in its diameter, to give a greater or lefs velocity to the rope.

The common expanding rigger is a caft-iron wheel with twelve arms, in each of which a groove is formed, extending nearly from the centre to the circumference, as A A, *fig.* 5. *Plate* XXVI. *Mechanics.* Againft each arm a piece of wood is placed, which has a rebate fitting into the groove, and a fcrew-bolt paffing through both wood and the arm of the wheel; a nut fcrewed upon the bolt faftens the bolt and wood at any place in the groove: each piece of wood has a groove in it to receive the rope which paffes round the wheel. The diameter of this rigger can be altered by loofening the nuts, then placing the pieces of wood all in one circle of the propofed diameter, and faftening them there by the nuts. To facilitate the placing of the pieces of wood in one circle, each arm is divided into inches, and numbered from the centre.

Mr. Andrew Flint, of London, lately received a premium of fifty guineas from the Society of Ats, for two expanding band wheels, or riggers. *Figs.* 5, 6, and 7, are different views of the firft of thefe; A A is a caft metal wheel with twelve arms, each divided by a groove from near the centre to the circumference: thefe grooves receive rebates on the backs of twelve racks *a a*, *figs.* 6 and 7, which have projecting pieces *b*, *b*, with grooves to contain the endlefs rope *d d*. In *fig.* 5. which is a back view of the wheel *e e*, are nuts, which draw up the racks to flide in the grooves without fhake, yet freely to and from the centre: the racks are moved all together by means of a circular plate *d d*, which has a fpiral rib upon it entering between the teeth of each rack, fo that when the plate is turned round, all the racks move to or from the centre at once: the fpiral plate *d d* is fcrewed to an iron crofs, which fits upon the axis *f f*, and is turned round by a pinion *g* of fix teeth, working into a ring of teeth made in the infide of the fpiral plate *d*.

Another method of accomplifhing the fame object is by means of twelve fcrews *b* (*figs.* 8. and 9) pointing to the centre of the wheel; they are are all moved together by means of equal bevelled wheels fixed on them; by this means the fcrews are turned about contrary ways alternately: they muft, therefore, be alternately cut right handed and left handed, that they may produce the fame effect. The fcrews are turned, when the diameter of the rigger is to be altered, by a winch put upon any of the three fquares *h*, *h*, *h*, on the ends of the fcrews. In this machine the number of fcrews muft be even.

Figs. 10, 11, and 12, are drawings of an expanding rigger contrived by the writer of this article: it confifts of two wheels of caft-iron A, A, (*figs.* 10, 11, and 12.) which have fixteen fectorial apertures marked *a*, which leave fixteen arms between them; the arms and the fpaces are exactly equal, and each arm has a triangular piece of wood *b d e*, (*fig.* 12.) fcrewed upon it, by four fcrews going through the arm into the wood, which is alfo kept firm and perpendicular to the face of the wheel, by a rib *f*, (*fig.* 11.) which projects from each arm, and is let into a groove cut in the wood. The wheels have fockets *g*, *g*, (*figs.* 10 and 12.) which are bored out with a very true cylindrical hole to receive the fhaft or fpindle B B of the rigger, which is turned in the lathe to fit the fockets without fhake, yet at the fame time allowing them to move backwards and forwards upon the axis B B. The wheels are put together upon the fpindle facing each other, the wooden triangles of one wheel entering the fpace between the arms of the other, as is fhewn in *figs.* 10 and 12; in this manner it is plain that the points, or rather plane, of interfection of the triangles *b d e* of each wheel, will form a circular groove to receive a rope, which groove can be increafed in its diameter by advancing the wheels towards each other, or diminifhed by fetting them farther apart, as in *fig.* 10. The wheels are prevented from turning on the fpindle by means of a fillet, which is inferted partly into a groove cut in the axis, and partly in another groove made in the focket of the wheel. The wheels may be brought nearer together, or thrown farther apart, by two fcrews *h*, *h*, (*fig.* 12.) which have fockets in one wheel, and are tapped into the other: two equal cog-wheels *i*, *i*, are keyed faft upon the fcrews, and an intermediate cog-wheel *k*, placed loofely upon the main axis between them, caufes both fcrews to turn at the fame time. A more fimple method of altering the diameter is by pufhing the wheels together by hand, and faftening them to the axis by fcrews *e*, *e*, *fig.* 10.

Expansion

EXPANSION, in *Metaphyfics*, expreffes the idea we have of lafting or preferving diftance, *i. e.* of diftance, all the parts whereof exift together.

Expansion, from the Latin *expando*, in *Philofophy*, denotes the increment of furface or of bulk, of which natural bodies are fufceptible. With refpect to the expanfion of furface, fee the articles Ductility and Gold *Beating*.

Bodies of every kind, as far as we are acquainted with them, are expanded in bulk by heat, and are contracted by cold; and to this law there are very few exceptions, which will be noticed in due time. The expanfions, or the increments of bulk, are not exactly proportional to the increments of heat in the fame body; nor are different bodies expanded alike by the like elevation of temperature. Thus, if a quantity of water be increafed one inch in bulk, by the communication of ten degrees of heat, the communication of twice or thrice as much more heat will not caufe it to expand two or three inches more. Alfo, if a rod of gold, and another fimilar rod of glafs, be heated to the fame degree, their increments of bulk, arifing thereby, will not be equal, the gold expanding more than the glafs.

Of the three principal ftates of natural bodies, *viz.* folids, liquids, and elaftic fluids, the folids are expanded leaft; the liquids are expanded more than the folids, but the elaftic fluids are expanded a vaft deal more than the liquids. The knowledge of the precife quantities of thefe expanfions of bodies is of great ufe in philofophy, in mechanics, and in other fcientific fubjects; hence no pains have been fpared by philofophers to inveftigate and afcertain them; various inftruments have been contrived for that purpofe; innumerable experiments have been inftituted; and a great many ufeful refults have been obtained. Of thefe refults we fhall now endeavour to give a regular and diftinct account.

The inftruments which have been contrived for the purpofe of meafuring the expanfions of folids arifing from an elevation of temperature, are called *pyrometers*. The objects which muft be had in view in the conftruction of pyrometers, are to form a fteady frame, wherein folids of a certain length may be applied either fucceffively, or feveral of them at the fame time, fome contrivance by which thofe metallic bodies may be heated to any required degree, and a mechanifm capable of meafuring the increafe of bulk which is caufed by the heat; and this may be accomplifhed by means of multiplying wheels, by levers, by fcrews, by a microfcopical micrometer, or otherwife. See Pyrometer.

Some of the firft determinations of the expanfion of bodies, that may be confidered as being fufficiently accurate, were made by Mr. Ellicot with a pyrometer of his contrivance. Mr. Ellicot determined the proportional expanfions of feven metallic bodies by the fame elevation of temperature. They are as follows:

Gold.	Silver.	Brafs.	Copper.	Iron.	Steel.	and Lead.
73.	103.	95.	89.	60.	56.	149.

Mr. Smeaton contrived a much better pyrometer, and with it he determined the expanfions of feveral folids. Mr. De Luc alfo contrived a pyrometer of a peculiar conftruction; but Mr. Ramfden's pyrometer is fuperior to any other contrivance of the kind.

The following table fhews, in parts of an inch, how much one foot length of different fubftances is expanded by 180° of heat, Fahrenheit's fcale, between the freezing and the

boiling points of water. To the firſt ſeven ſubſtances, (which were examined in Mr. Ramſden's moſt accurate pyrometer,) there are added the expanſions for a ſingle degree of heat. The others were determined by Mr. Smeaton with his pyrometer.

	Fahrenheit's Scale.	
	By 1°	By 180°.
Standard braſs ſcale, ſuppoſed to be Hamburgh braſs - -	0.0001237	0.0222646
Engliſh plate braſs in form of a rod - - - - - -	0.0001262	0.0227136
Engliſh plate braſs in form of a trough -	0.0001263	0.0227386
Steel rod -	0.0000763	0.0137368
Caſt-iron priſm	0.0000740	0.0133126
Glaſs tube -	0.0000517	0.0093138
Solid glaſs rod	0.0000539	0.0096944
White glaſs barometer tube		0.0100
Martial regulus of antimony		0.0130
Bliſtered ſteel -		0.0138
Hard ſteel - -		0.0147
Iron - - -		0.0151
Biſmuth - -		0.0167
Copper hammered -		0.0204
Copper eight parts, with tin one part - - - - - -		0.0218
Caſt braſs - - - - -		0.022[illegible]
Braſs ſixteen parts, with tin one part - - - - - -		0.0229
Braſs wire - - - - -		0.0232
Speculum metal - - -		0.0232
Spelter ſolder, *viz.* braſs two parts, zinc one - - -		0.0247
Fine pewter - - - -		0.0274
Grain tin - - - - -		0.0298
Soft ſolder, *viz.* lead two parts, tin one - - - -		0.0301
Zinc eight parts, with tin one, a little hammered - - -		0.0323
Lead - - - - - -		0.0344
Zinc or ſpelter - - - -		0.0353
Zinc hammered half an inch *per* foot - - - - - -		0.0373

Iron, inſtead of being condenſed into a ſmaller bulk, expands in its tranſition from a fluid into a ſolid ſtate; ſo that a quantity of iron occupies more room in the ſolid form than it does in a fuſed ſtate.

Dr. Wollaſton, in order to form ſome eſtimate of the comparative rate of expanſion of platina and palladium, ſays, "I rivetted together two thin plates of platina and palladium, and obſerving that the compound plate, when heated, became concave on the ſide of the platina; I aſcertained that the expanſion of palladium is in ſome degrees the greater of the two. By a ſimilar mode of compariſon I found that palladium expands conſiderably leſs than ſteel by heat." Phil. Tranſ. for 1805.

It muſt be remarked with reſpect to the expanſion of glaſs, that ſometimes glaſs tubes are extended more than ſolid glaſs rods: their dilatation, however, is not conſtant; for tubes of different diameters, or of different ſorts of glaſs, are expanded differently by the like degrees of heat.

Wood is not expanded much longitudinally; that is, in the direction of its fibres, by heat, and this is particularly the caſe with deal and other ſtraight-grained wood. Probably, upon the whole, the longitudinal expanſion of wood is leſs than that of glaſs. It has been obſerved, (eſpecially by Dr. Rittenhouſe, Tranſ. of the American Phil. Society) that very dry and ſeaſoned wood, if not expoſed to a very high or to a very low temperature, will expand in length pretty regularly: otherwiſe its expanſion by heat, and its contraction by cold, are very irregular: for they ſeem to depend partly upon the heat, and partly upon the moiſture, which the wood acquires in certain circumſtances, and is deprived of in others.

It is hardly neceſſary to mention, that the ſolids of the preceding table contract their dimenſions by cooling as much as they are expanded by heating; thus, for inſtance, if a yard length of any particular metallic body, by being heated 100° above the actual temperature of the atmoſphere, be lengthened one fiftieth part of an inch; afterwards, when cooled down to the temperature of the atmoſphere, it will be found to have loſt exactly that fiftieth part of an inch which it had acquired by heating.

From the experiments hitherto made on the expanſions of ſolids by heat, no correſpondence has been obſerved between the expanſions and the quantities of caloric they are capable of abſorbing. The fuſibility of metals ſeems to coincide with the dilatations; platina, the leaſt fuſible of the metals, dilates the leaſt; lead dilates moſt; and the moſt fuſible glaſs is alſo the moſt dilatable. We may therefore conclude with Mr. Berthollet, that bodies are ſo much the more expanſible, the leſs caloric they require to change their conſtitution from ſolid to liquid, and from liquid to gaſes or vapours.

There is a ſubſtance which expands when heated; but does not contract when cooled; and of this ſingular property Mr. Wedgwood availed himſelf for the conſtruction of his ingenious thermometer for meaſuring the higheſt degrees of heat; *viz.* thoſe degrees which exceed the ſcale of the mercurial thermometer. (See Thermometer.) The ſubſtance alluded to is the argillaceous earth or clay, and it appears that the above-mentioned property belongs, more or leſs, to argillaceous bodies of every kind. This property may at firſt ſight appear to be an unaccountable exception from the general law: the difficulty, however, will vaniſh, if it be conſidered that bodies of the argillaceous genus contain a conſiderable quantity of water, and that the contraction of theſe bodies, when expoſed to the action of a ſtrong fire, is in great meaſure due to the eſcape of the water, and hence they do not contract by ſubſequent cooling.

The method of meaſuring the expanſions of fluids is to incloſe them in a certain veſſel, and to meaſure that part of the cavity of the veſſel, which is occupied by the fluid under trial, in different temperatures. It is evident that the ſubſtance of the veſſel is likewiſe expanded by the heat, and of courſe the cavity of the veſſel is enlarged. Therefore, when we find that the bulk of the fluid is increaſed, that increment is only the difference between the enlarged capacity of the veſſel and the increaſed bulk of the fluid. This ſhews the neceſſity of forming thoſe veſſels of ſuch ſubſtances as are leaſt expanſible by heat. Indeed glaſs is the ſubſtance which is univerſally uſed for ſuch purpoſes, both on account of its little expanſibility, and of its tranſparency; beſides its having other uſeful properties. A glaſs veſſel, filled to a certain degree with a liquid, for the purpoſe of ſhewing the expanſions of that liquid in different temperatures, or for the purpoſe of ſhewing the temperature of the correſponding expanſion of that liquid, is called a thermometer; *viz.* a meaſure of the temperature. See Thermometer.

The propereſt ſhape for a thermometer is that of a long

tube with a narrow bore, having a globular cavity at one end; which, familiarly ſpeaking, may be called a globular glaſs bottle with a long and narrow neck. The globular cavity, and part of the tube of one of theſe veſſels, is filled with the liquor whoſe expanſion is to be examined, and the veſſel is then heated, in conſequence of which the liquor, which is contained in it, is expanded, and not being able to extend itſelf any other way, all the increment of bulk muſt be manifeſted in the tube; *viz.* the ſurface of the fluid will riſe in the tube; or, if cooled, it will deſcend in it. If the ſame veſſel of the above-mentioned ſhape be ſucceſſively filled with different fluids, and with each fluid it be expoſed to certain degrees of temperature, (which muſt be determined by an accurate thermometer,) the proportional expanſions of the different fluids may thereby be aſcertained. The ſame object may be obtained by filling ſeveral ſuch veſſels with the different fluids, that are to be examined, and heating or cooling them all at the ſame time; but in this caſe the correſponding capacities of the different veſſels muſt be previouſly aſcertained; which may be done by filling all the veſſels with the ſame kind of fluid, and expoſing them all to different degrees of temperature; ſo that the correſponding elevations of the fluid in the different veſſels may be marked on the tubes. Theſe veſſels are afterwards emptied and filled again with the fluids, &c. Thus the proportional expanſions of liquids may be determined; but when the actual or abſolute increaſe of bulk is required, then the capacity of the veſſel muſt be accurately gauged. This meaſurement of the capacity may be accompliſhed in the following manner. In the firſt place weigh the empty glaſs tube; ſecondly, fill part of the tube with a convenient fluid, (mercury, for inſtance, which is the fitteſt for ſuch purpoſes); thirdly, meaſure the length of the tube which is occupied by the mercury, and weigh the inſtrument a ſecond time; then, by ſubtracting this ſecond weight from the former, you will have the weight of mercury which fills up a certain length of the cavity of the tube; fourthly, fill the bulb of the veſſel entirely with mercury, and weigh the veſſel a third time. This weight being ſubtracted from the firſt, *viz.* from that of the empty veſſel, will leave the weight of the mercury in the bulb. Now, having the weight of the mercury in the bulb, as well as of that which fills a certain length of the tube, the ratio of the former to the latter may be eaſily determined by ſimple diviſion. Alſo the abſolute quantity in bulk of the former is obtained from the well known ſpecific gravity of mercury, and from the weight of a cubic inch of diſtilled water, which (when the barometer is at 29.74 inches, and Fahrenheit's thermometer at 66°) is equal to 252.42 grains Troy; one pound Troy being equal to 5760 of thoſe grains. An Engliſh cubic inch of mercury of the ſpecific gravity 13.6 weighs 3443.2 Engliſh grains. Inſtead of mercury, ſome other fluid may be employed for this purpoſe; but not ſo conveniently as mercury. The expanſions of a fluid, which are cauſed by different degrees of heat, may likewiſe be determined by aſcertaining the ſpecific gravity of that fluid in different temperatures; for the ſpecific gravity decreaſes in proportion as the fluid is expanded, and *vice verſâ;* but this method is not capable of as much accuracy as the former.

Liquids differ from each other in regard to their expanſibility; ſome expanding more than others. Alſo the expanſions of the ſame liquid by equal degrees of heat are not quite regular; and it has been obſerved that this irregularity is greater when they approach the ſtate of vapour. Upon the whole, mercury has been found to be expanded by heat more regularly that any other fluid; yet its increments of bulk are not perfectly regular. Mr. De Luc, with great care and patience, has endeavoured to aſcertain the real expanſibility of mercury, or rather the real quantities of heat that are required for expanding mercury arithmetically, *viz.* by equal augmentations. Theſe are expreſſed in the following table, the firſt column of which contains the degrees of Reaumur's ſcale, from five to five, which are equal parts; the ſecond ſhews the real quantities of heat which are required to raiſe the mercury to the correſponding degrees, where *z* is a fixt but unknown quantity; and the third column ſhews the differences of thoſe quantities. De Luc's Recher. ſur les Modif. de la Atmoſph. 1772, p. 309.

	Mercurial Thermom.	Real quantities of heat.	Real differences of heat correſponding to the variations of the Mercury in the thermom. from 5 to 5 degrees.
Point of boil. water	80°	$z + 80.00$	
	75	$z + 75.28$	−4.72
	70	$z + 70.56$	−4.72
	65	$z + 65.77$	−4.79
	60	$z + 60.96$	−4.81
	55	$z + 56.15$	−4.81
	50	$z + 51.26$	−4.89
	45	$z + 46.37$	−4.89
	40	$z + 41.40$	−4.97
	35	$z + 36.40$	−5.00
	30	$z + 31.32$	−5.08
	25	$z + 26.22$	−5.10
	20	$z + 21.12$	−5.10
	15	$z + 15.94$	−5.18
	10	$z + 10.74$	−5.20
	5	$z + 5.43$	−5.31
Point of melt. ice	0	z	−5.43

From the third column it appears, that the differences of heat requiſite to make equal and progreſſive additions to the bulk of the mercury, though not exactly equal, yet are not very far from the ratio of equality. If the bulk of a quantity of mercury, at the temperature of 32° Fahrenheit's ſcale, be conceived to be divided into 100,000 equal parts, and then be heated as high as the temperature of boiling water; (*viz.* 212°) its bulk will thereby be increaſed by 1836 of thoſe parts.

The expanſion of water is attended with a ſingular deviation from the general law; *viz.* this fluid is expanded by heat from about the 40th degree of Fahrenheit's thermometer upwards; but below 40° its bulk is expanded by a farther decreaſe of heat, or increaſe of cold; and in fact ice is lighter than water, ſo as to float upon it; the ſpecific gravity of ice being to that of water nearly as 7 to 8. The bulk of ice is to that of the water, when the ice is melted, as 9 to 8 very nearly. The bulk of water, from its moſt contracted ſtate at the temperature of 40°, increaſes continually; but that increaſe is not very regular; for inſtance, the increaſe of bulk from 180° to 212°, is conſiderably greater than from 40° to 72°. If the bulk of water at 40° be called 1, its bulk at 212 will be 1.04785. Beyond that degree of heat water becomes vapour; *viz.* an elaſtic fluid, and the formation of this elaſtic fluid on the ſides of the veſſel within the water, forms the bubbles, the eſcape-

of which conſtitutes the boiling. The bulk of ſteam at the boiling point is ſomewhat leſs than 1800 times the bulk of the water from which it originated.

The expanſion of freezing water is not owing to the extrication of air; for water deprived of air expands like other water in freezing. Mr. Mairan attributes it to a ſtrong tendency the particles of water have to arrange themſelves into ranks and lines, which croſs one another at angles of 60° and 120°. This tendency ſeems to begin at the temperature of 40°. The expanſion of freezing water has a prodigious force. It is owing to this that in hard froſts timber is burſt, plaiſter is removed from walls, and even iron mortar ſhells filled with water, and accurately ſtopped, have been burſt by the freezing of the water.

This ſingular property of water, *viz.* its expanding from the temperature of 40° downwards, ſo as to become lighter and lighter in proportion as it becomes colder and colder, is a moſt ſtriking inſtance of the wiſdom of the Creator, and is a property of immenſe conſequence to the very exiſtence of animals and vegetables. A quantity of water is indiſpenſably neceſſary to animals and to vegetables at all times of the year. In winter, when the cold air freezes the ſurface of the water, that effect ſeldom penetrates lower than two or three feet. Below that depth the water continues fluid, and the cruſt of ice itſelf contributes to preſerve its fluidity. The heat of the earth, which has been acquired during the ſummer, undoubtedly prevents the formation of ice below a certain depth. But if water in cooling had continued to increaſe in ſpecific gravity, and had ice been actually heavier than water, the heat of the earth would not have been ſufficient to prevent the total freezing of all the waters of lakes, ſeas, rivers, &c. "For," ſays count Rumford, "as the particles of water on being cooled at the ſurface would, in conſequence of the increaſe of their ſpecific gravity, on parting with a portion of their heat, immediately deſcend to the bottom, the greateſt part of the heat accumulated during the ſummer in the earth, on which the water repoſes, would be carried off and loſt before the water began to freeze; and when ice was once formed, its thickneſs would increaſe with great rapidity, and would continue increaſing during the whole winter; and it ſeems very probable that in climates which are now temperate, the water in the large lakes would be frozen to ſuch a depth in the courſe of a ſevere winter, that the heat of the enſuing ſummer would not be ſufficient to thaw them; and ſhould this once happen, the following winter would hardly fail to change the whole maſs of its waters to one ſolid body of ice, which never more could recover its liquid form, but muſt remain immoveable till the end of time." (7th Eſſay.)

The following table ſhews the expanſions of the principal liquids that have been ſubmitted to ſuch experiments, according to Mr. De Luc's obſervations. With reſpect to this table it muſt be underſtood that different thermometers (each being filled with a particular fluid, ſuch as is mentioned at the top of each column, and each being divided into 80 equal parts between the freezing and the boiling points of water) are placed with their bulbs in the ſame veſſel full of water, and that the water is gradually heated. Then when the mercurial thermometer ſtands at 5°, 10°, 15°, &c. the ſurfaces of the fluids in the other thermometers will be found at the degrees which ſtand on the ſame levels; for inſtance, when the mercurial thermometer ſtands at 40°, the water thermometer will be found to ſtand at 20°.5, the ſpirit thermometer will be found to ſtand at 35°, the oil thermometer at 39°.2, &c.

	Mercury.	Water	Water ſaturated with ſalt.	Alcohol.	Alcohol 3 parts, water 1.	Alcohol and water equal parts.	Alcohol 1 part, water 3.	Oil of olives.
Boiling water	80°	80.0	80.0	80.0	80.0	80.0	80.0	80.0
	75	71.0	74.1	73.8	73.7	73.2	71.6	74.6
	70	62.0	68.4	67.6	67.5	66.7	62.9	69.4
	65	53.5	62.6	61.5	61.5	60.6	55.2	64.4
	60	45.8	57.1	55.5	55.8	54.8	47.7	59.3
	55	38.5	51.7	50.3	50.2	49.1	40.6	54.2
	50	32.0	46.6	45.1	44.9	43.6	34.4	49.2
	45	26.1	41.2	40.0	39.7	38.4	28.4	44.0
	40	20.5	36.3	35.0	34.8	33.3	23.0	39.2
	35	15.9	31.3	30.1	29.8	28.4	18.0	34.2
	30	11.2	26.5	25.5	25.2	23.9	13.5	29.3
	25	7.3	21.9	20.9	20.7	19.4	9.4	24.3
	20	4.1	17.3	16.5	16.2	15.3	6.1	19.3
	15	1.6	12.8	12.0	11.8	11.1	3.4	14.4
	10	0.2	8.4	7.9	7.7	7.1	1.4	9.5
	5	0.4	4.2	3.9	3.8	3.4	0.1	4.7
Freezing	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	5		4.1					
	10		8.0					

The expanſions of elaſtic fluids, ſuch as common air, the gaſes, and vapours, are more difficultly aſcertained; for the expanſions of thoſe fluids are occaſioned by a diminution of preſſure, as well as by an increaſe of temperature; and it is difficult to ſubject any of thoſe fluids to the action of one of theſe cauſes only at a time, in order that the effect of each may be duly eſtimated.

When common air is acted upon by preſſure only, independent of any alteration of temperature, its bulk is found to increaſe and to decreaſe in the inverſe proportion of the preſſure; thus, the air cloſe to the ſurface of the earth is compreſſed into the bulk which we experience, by the ſuperincumbent atmoſphere. If that preſſure be increaſed, the bulk of the lower air will be contracted, which is manifeſted by an augmentation of its weight; if that preſſure be diminiſhed, the bulk of the lower air will be increaſed, as is manifeſted by a diminution of its weight. And this expanſion and contraction of the air is exactly but inverſely proportional to the preſſure; ſo that a double preſſure will compreſs it into half the ſpace, a treble preſſure into one third of the original ſpace, &c. The ſame thing, *mutatis mutandis*, may be ſaid of the removal of preſſure, and of the expanſion thereby ariſing. This elaſticity of the air has not been found to be impaired by a long continuance of the preſſure; for air has been left during ſeveral years very much compreſſed in proper veſſels, wherein there was nothing that could have a chemical action upon it; and afterwards on removing the unuſual preſſure, and replacing it in the ſame temperature, the air has been found to recover its original bulk. It is not known how far a quantity of air may be expanded by removing the preſſure, nor how much it may be compreſſed by increaſing the preſſure; for no experiments have as yet been able to aſcertain either limit.

The inſtrument, in which the expanſion of air is tried, has been called *manometer*, (which ſee,) It is a ſort of large air thermometer, conſiſting of a tube five or ſix feet long, having a bulb at one end, and being open at the other end. The bore of the tube is about a 20th of an inch in diameter. A ſmall quantity of quickſilver is placed in ſome

part of the cavity of the tube, and the expanſion of the air in the bulb, when heated, forces the quickſilver to move towards the open end of the tube. The degree of heat to which the manometer is expoſed is meaſured by means of a thermometer; the quantity of expanſion of the air is meaſured by gauging the manometer, and making marks on the tube, which may indicate parts of the cavity of the tube that are proportional to the capacity of the manometer; as for inſtance 100dths, 1000dths, &c. By placing the manometer horizontal or vertical, either with the bulb downwards or upwards, the air in it may either be left of the natural denſity, or it may be condenſed, or, laſtly, it may be rarefied; for when the manometer ſtands horizontal, the quickſilver in the tube does not preſs upon the air in the bulb, nor on that of the atmoſphere; when the bulb is downwards, the quickſilver preſſes upon the air of the manometer, and when the bulb is upwards, the quickſilver preſſes againſt, and counteracts, in ſome meaſure, the gravity of the atmoſphere. Hence this preſſure, and this expanſion of the air within the manometer, may be increaſed to any required degree by increaſing the quantity of quickſilver within the tube: and thus the expanſibility of common, or of condenſed, or of rarefied air, may be tried. The expanſion of air, by the ſame degrees of heat, differs according to its denſity, and to the quantity of moiſture it contains; nor are the increments of its bulk proportional to the degrees of temperature.

It appears from Col. Roy's very numerous experiments (Phil. Tranſ. vol. 67th) that 1000 parts of air, of the denſity of the common atmoſphere, at 0° of heat, become 1484.21 at 212°; *viz.* are expanded 484.21, by 212° of heat.

1000 parts of air loaded with 2½ atmoſpheres, are expanded 434 of thoſe parts, by 212° of heat.

1000 parts of air preſſed only with ⅚ths of an atmoſphere, are expanded nearly 484 of thoſe parts by 212° of heat.

1000 parts of air preſſed with ⅕th of an atmoſphere, are expanded about 141 parts by 180° of heat; *viz.* from the freezing to the boiling point of water.

"From theſe laſt experiments," Col Roy ſays, "it would ſeem that the particles of air may be ſo far removed from each other, by the diminution of preſſure, as to loſe a very great part of their elaſtic force."

The above-mentioned expanſions of air are by no means regular: *viz.* they are not proportional to the number of the degrees of heat. The maximum of expanſion takes place between 52° and 72°: and the minimum is conſtantly at the boiling point of water. Moiſt air expands a great deal more than dry air, eſpecially when it approaches the boiling point of water; ſo that between 192°, and 212°, moiſt air expands about eight, or nine, times as much as dry air in ſimilar circumſtances.

The expanſions of gaſes may be tried and determined in the ſame manner as the expanſion of common air. From a long ſeries of experiments Meſſrs. Guyton and Prieur deduced a dilatation peculiar to each gas; but Mr. Guy-Luſſac has ſhewn, that all gaſes, without exception, poſſeſs the ſame expanſibility at the ſame degree of temperature, and that the preſence of water in gaſes occaſioned the errors into which his predeceſſors had fallen. He is led to conclude from his experiments made on gaſes reduced to the utmoſt degree of dryneſs, that 100 parts of each of the permanent gaſes acquire an increaſe of $\frac{1}{213}$ by every degree of the thermometer from 0° to 80° Reaumur's ſcale. Vapours, he alſo thinks, follow the ſame laws of dilatation as gaſes, provided the temperature be ſufficiently elevated to keep them in the elaſtic ſtate. Therefore, Mr. Chaptal ſays, it may be laid down as a principle, that gaſes and vapours are equally dilatable, and equally compreſſible; but it will be neceſſary to be more particular with reſpect to the expanſibility of the vapour of water, upon the elaſticity of which numerous natural phenomena, and the action of ſeveral important machines, depend.

Mr. Schmidt alſo made a ſeries of experiments upon the expanſibility of air, made as dry as poſſible by expoſure to hot potaſh. He found the expanſion of a quantity of air which meaſured one inch at the freezing point, *viz.* at the temperature of 0° Reaumur's thermometer, to expand as below.

Degrees of Reaumur.	Expanſion of one inch.
1	0.0044675
4	0 0178700
8	0.035740
12	0 0536100
16	0.0714800
20	0.0893500
24	0.1072200
28	0.12509[illegible]9
32	0.1429600
36	0.1608300
40	0.1787[illegible]0[illegible]

This table alſo ſhews, by its differing from the reſults of D'Amontons, De Luc, Lambert, Schuckburgh, Berthollet, and others, that thoſe gentlemen operated upon air more or leſs charged with moiſture. They alſo took the barometers at different altitudes. In Mr. Schmidt's experiments the barometer was taken at 29,841 Engliſh inches. Theſe variations of the rates of expanſibility of moiſt air, ſaturated at different temperatures, Schmidt attributes to the variations of the degrees of affinity between air and vapour.

Water heated to the 212th degree of Fahrenheit's thermometer (or thereabout, for the different gravity of the atmoſphere occaſions a conſiderable difference) overcomes the ordinary preſſure of the atmoſphere and becomes ſteam, an elaſtic ſubſtance, the bulk of which at that point is ſomewhat leſs than 1800 times the bulk of the water from which it originated. Beyond that point vapour is expanſible in a moſt aſtoniſhing degree; for 30° more of heat (*viz.* the temperature of 242°) will double the elaſtic force of ſteam; 30° more added to that (*viz.* the temperature of 272°) will render the elaſtic force of ſteam nearly equal to four atmoſpheres; and ſo forth. This immenſe expanſibility of ſteam, when the heat which produces it is quickly ſupplied, is capable of producing prodigious effects. When water is cauſed to boil in a veſſel upon a common fire, the heat which is communicated cannot convert all the water at once into ſteam; but if the quantity of water be ſmall in proportion to the heat which can be communicated in a given time, then the converſion of water into ſteam is quickened to any degree, and it may be rendered inſtantaneous; in which caſe it produces a ſudden and violent expanſion, or an exploſion. A drop of rain in boiling linſeed oil, falls to the bottom, is inſtantly converted into vapour, and occaſions dangerous conſequences. "It has ſometimes," Dr. Black ſays in his Chemical Lectures, "happened that a perſon, by careleſsly ſpitting into a copper foundery, has occaſioned an exploſion that deſtroyed the whole building." Count Rumford attributes the vaſt force of gun-powder to the ſudden converſion into vapour of that quantity of water which naturally enters into the compoſition of that powder; it being a component of the nitre. Phil. Tranſ. for 1797.

Water at the temperature of 212° is converted entirely into ſteam, or rather, under the ordinary preſſure of the atmoſphere, water cannot be heated higher than 212°; but water is gradually converted into ſteam or vapour at a much lower temperature. Mr. Pictet inſtituted a ſeries of experiments on the elaſticity of pure vapour in low temperatures. He found that a grain of warm water in vacuo evaporates in forty minutes in the temperature of 38° Fahr. under a receiver containing 1452 Engliſh cubic inches, but that it did not diffuſe itſelf equally in leſs than ſix hours and then raiſed the hygrometer from 17° to 60°, that is, 43°; and during this whole time the cold under the receiver was conſtantly decreaſing, though ſlowly: which decreaſe undoubtedly contributed to the diffuſion of the vapour. Eſſais de Phyſique, p. 157.

The beſt, or moſt extenſive experiments upon the expanſive force of the ſteam of water, and of the ſteam of alcohol, were made by the Chev. de Bettancourt; and are related by Prony in the ſecond volume of his "Architecture Hydraulique;" from which the following compendious ſketch is derived.

The fluid with which the experiments were made was confined in a very ſtrong copper boiler, being eight inches at its greateſt diameter, and fourteen inches in height. The upper part of it was cloſed by a cover made of copper, through which paſſed three tubes. The firſt ſerved to introduce the fluid into the boiler, and could be cloſed by means of a ſcrew. The ſecond was occupied by a thermometer, having its ball about two inches above the bottom of the boiler, and the ſcale, which was on the outſide, contained from 0° to 110° of Reaumur. To the third was adapted a bent barometer tube, having two lines of internal diameter; the aſcending branch of which was 110 inches in length. By means of a lateral cock a communication was eſtabliſhed between the boiler and an air pump, which ſerved to make a vacuum before the fire was kindled in the furnace below the apparatus. This circumſtance of evaporation in a vacuum forms an eſſential difference between the experiments of Bettancourt and thoſe made before by Ziegler, and renders them applicable to the theory of the ſteam-engine, where the vapour acts in a ſpace freed from air.

A vacuum having been made in the boiler, the mercury brought as nearly as poſſible to a level in the two branches of the barometric tube, and the thermometer reduced to zero by means of ice, the ice was removed, and a fire was kindled, which was excited gently and with much equality, that the thermometer paſſed over about a degree per minute. One perſon then ſtood by to obſerve the barometer, and another to obſerve the thermometer, and each kept a regiſter from degree to degree of the preſſure and correſponding temperatures; the preſſure being expreſſed by the height, in French inches, of the columns of mercury, which roſe above the level in the long branch of the barometer.

Theſe obſervations of the expanſive force of the ſteam of water furniſh 110 reſults, proceeding from degree to degree of the thermometer, and beginning at zero. Theſe reſults are contained in the following table, where the degrees of preſſure are expreſſed in French inches of perpendicular height of mercury, and the temperature is denoted according to Reaumur's ſcale. The experiments on the expanſive force of the ſteam of alcohol were made by the like proceſs, and with the ſame apparatus.

Table of the Expanſive Force of the ſteam of Water and of Alcohol.

Temperature.	Preſſure.		Temperature.	Preſſure.		Temperature.	Preſſure.	
	Water.	Alcohol.		Water.	Alcohol.		Water.	Alcohol
0	0.00	0.00	37	2.45	5.55	74	20.60	48.10
1	0.00	0.00	38	2.57	6.00	75	21.75	50.20
2	0.00	0.00	39	2.75	6.45	76	22.90	52.60
3	0.00	0.05	40	2.92	6.90	77	24.15	55.30
4	0.02	0.09	41	3.10	7.35	78	25.50	57.90
5	0.02	0.12	42	3.27	7.82	79	26.67	61.00
6	0.05	0.18	43	3.47	8.37	80	28.00	63.80
7	0.07	0.25	44	3.70	8.92	81	29.60	66.90
8	0.10	0.32	45	3.95	9.48	82	31.30	69.8[illegible]
9	0.12	0.38	46	4.25	10.15	83	33.00	73.40
10	0.15	0.45	47	4.45	10.80	84	34.60	76.90
11	0.18	0.50	48	4.75	11.5	85	36.45	79.60
12	0.22	0.62	49	5.00	12.20	86	38.10	83.60
13	0.27	0.72	50	5.35	12.35	87	40.00	87.10
14	0.30	0.82	51	5.70	13.75	88	42.20	90.80
15	0.35	0.93	52	6.05	14.60	89	44.30	95.00
16	0.40	1.02	53	6.50	15.50	90	46.40	98.00
17	0.45	1.12	54	6.90	16.40	91	48.40	
18	0.52	1.25	55	7.32	17.65	92	50.50	
19	0.58	1.38	56	7.85	18.85	93	53.00	
20	0.65	1.52	57	8.40	20.00	94	55.30	
21	0.75	1.65	58	8.85	21.20	95	57.80	
22	0.82	1.80	59	9.35	22.30	96	60.50	
23	0.90	1.95	60	9.95	2[illegible].70	97	63.40	
24	0.97	2.10	61	10.40	24.80	98	66.2[illegible]	
25	1.05	2.32	62	11.00	26.10	99	69.00	
26	1.12	2.52	63	11.70	27.40	100	71.80	
27	1.22	2.75	64	12.40	28.90	101	75.00	
28	1.32	2.95	65	13.20	30.60	102	78.20	
29	1.42	3.20	66	13.80	32.00	103	81.00	
30	1.52	3.40	67	14.50	33.50	104	84.00	
31	1.65	3.70	68	15.25	35.10	105	86.80	
32	1.78	4.00	69	16.10	37.20	106	89.00	
33	1.90	4.30	70	16.90	39.40	107	91.30	
34	2.00	4.60	71	17.80	41.30	108	93.50	
35	2.15	4.95	72	18.70	43.50	109	95.60	
36	2.27	5.28	73	19.50	46.00	110	98.00	

The expanſive force of the ſteam of water has alſo been determined by Mr. Schmidt, with all the accuracy that the experiments ſeem to admit of: but the reſults which he has not ſtated for every degree of the thermometer, do not agree exactly with thoſe of Bettancourt. We deem it therefore neceſſary to ſubjoin thoſe reſults in the following ſhort table, wherein the temperature is expreſſed in degrees of Reaumur's thermometer, as in the preceding table, and the expanſive force in French inches of perpendicular altitude of mercury.

TABLE of the Expanſive Force of the pure vapour of Water, according to Mr. Schmidt.

Temperature.	Expanſive Force.	Temperature.	Expanſive Force.
0	0.0	22	1.01
5	0.11	25	1.30
6	0.15	27	1.42
10	0.28	30	1.93
12	0.38	33	2.23
13	0.14	35	2.68
15	0.55	37	3.20
16	0.61	39	3.40
18	0.76	40	3.64
20	0.90	80	28.00

Mr. Dalton has likewiſe endeavoured to determine the expanſive force of the vapour of water; but the reſults of his experiments nearly coincide with thoſe of the preceding tables, which ſuperſedes the neceſſity of ſtating them in the preſent article. See EVAPORATION.

From a careful examination of all the experiments made on this ſubject, Dr. Young has deduced a formula by which the expanſive force of ſteam may be determined for any degree of the thermometer, pretty near the real reſults of the experiments. The formula is as follows:

Let f denote the temperature according to Fahrenheit's thermometer, and e the number of inches in perpendicular height of mercury, which the ſteam is capable of ſupporting; then the formula is $e = .1781\ (1 + .006f)^7$.

The reader might perhaps expect to find in the preſent article the particulars relative to the expanſions of heat, and of electricity; but the uncertain natures of the fluids, to which the effects of heat and of electricity are attributed, beſides other conſiderations, oblige us to refer him to other parts of this Cyclopædia. See HEAT, CALORIC, and the articles belonging to electricity.

Dr. Gregory, in his Aſtron. p. 407, proves, that a globe of our air, of an inch diameter, if it were removed to the diſtance of a ſemidiameter of the earth, would expand itſelf ſo as to fill all the planetary region as far as, nay, far beyond the ſphere of Saturn. See AIR.

Felting

FELTING, in the *Manufactures*, denotes the operation by which the fur, hair, and wool of animals are wrought into a ſpecies of cloth, without either ſpinning or weaving. A hatter ſeparates the hairs from each other by ſtriking the wool with the ſtring of his bow, thus cauſing them to ſpring up in the air, and they then fall in every direction on the table, ſpread and diſtributed in ſmall flocks, which the workman covers with a cloth, ſlightly moiſtened; preſſing it with his hands, and moving the hairs backwards and forwards in different directions. In this manner the different fibres are brought againſt each other, and their points of contact conſiderably multiplied; and the agitation gives each hair a progreſſive motion towards the root, in conſequence of which the hairs become twiſted together. As the maſs becomes compact, the preſſure ſhould be increaſed, in order to keep up the progreſſive motion and twiſting of the hairs, which is thus performed with greater difficulty. The various fibres of the materials being thus by a gradual preſſure in different directions made to interweave and croſs each other, form a piece of ſtuff of a ſoft and ſpongy texture; upon this firſt piece is placed another, formed in the ſame manner, and ſometimes a third or fourth, according to the nature of the materials, and the intended thickneſs and conſiſtence of the work. Theſe different pieces are ſucceſſively brought together, and diſpoſed in a form ſuitable to the article which is to be fabricated; and in order to effect the coheſion, the operator uſes a number of preſſures and alternate motions in different directions, during which he preſerves the ſuppleneſs and flexibility of the material by ſlight aſperſions of water. The next operation is *fulling*, which ſee. The hair intended for the manufacturing of hats is always cut off with a ſharp inſtrument, and not pulled up by the roots; becauſe the bulb of the hair, which would come out with it in the latter caſe, would render the end which was fixed in the ſkin very obtuſe, and nearly deſtroy its diſpoſition to unite with the adjacent hairs. The hairs ſhould not be ſtraight like needles, for then there would be no compactneſs in the ſtuff. The fibres of wool having naturally a crooked form, that ſubſtance is well adapted to the operation of felting. The hair of beavers, rabbits, hares, &c. being ſtraight, cannot be uſed in felting, till it has been prepared for the purpoſe. See HAT.

Fermentation

FERMENTATION. The important procefs by which faccharine folutions are converted into intoxicating liquors, is one of the moft complicated in chemiftry, and the precife caufe of this change is as yet very imperfectly known. In the prefent article we fhall notice the conditions requifite to fermentation, the appearances that occur during the procefs, and the effential product of it, referving for the articles SPIRITS, *Diftilled*, and WINE, fome further particulars.

The only two fubftances indifpenfably requifite to the formation of a fermentable liquor are water and fugar.

No vegetable juice will ferment that is not fenfibly fweet, and from which a portion of fugar may not be extracted by chemical means. The ftrength of vinous liquors (other circumftances being the fame) is in direct proportion to the quantity of fugar contained in them before fermentation. The addition of fugar to the weakly fermentable juices will enable them to produce a ftrong full-bodied liquor, and the very effence of this procefs is the difappearance of the fugar, and the confequent production of alcohol.

With regard to the water, it does not appear how far this is an active ingredient in vinous fermentation, though it is fully afcertained that a particular degree of dilution is neceffary to this procefs: this confiftence exifts naturally in the juice of grapes, in the faccharine fap of many trees, and of other fpontaneoufly fermentable liquors; and if thefe very liquors be deprived by gentle evaporation of a confiderable portion of their water, the refidue will not ferment till the requifite confiftence is reftored by the addition of a frefh portion of water. On the other hand, if a faccharine mucilage is too dilute, the fermentation is very languid and imperfect.

But pure fugar and water alone will not ferment, and therefore fome other fubftance is alfo requifite. To this point the attention of chemifts has been often directed, but hitherto with but little fuccefs; indeed, the general refult of the experiments that have been made is, that feveral fubftances, very different in their other properties, will anfwer almoft equally well as a ferment. Muft, or the recent juice of the grape, contains, befide fugar and water, a quantity of vegetable acid, chiefly the tartareous, and one or more fubftances obfcurely defcribed under the names of mucilage and extract. Each of thefe is requifite to the fermentation of muft; for if any one is abftracted the procefs will not take place. A warm temperature is alfo requifite to fermentation. This varies according to the natural fermentability of the materials, and their bulk. Thus, grape-juice will readily begin to ferment at the temperature of about 60°, and the procefs is ftrong and vehement at 70° or 80°. The expreffed juice of the fugar-cane is fo exceffively prone to fermentation, that in the climate of the Weft Indies the procefs would begin in ten minutes, or a quarter of an hour; and hence, as fermentation is the deftruction of the fugar, it is neceffary, in making fugar, to counteract this tendency in the expreffed juice as fpeedily as poffible, which is effected merely by bringing it to a fcalding heat. A low temperature, as that of freezing water, is equally efficacious in preventing or arrefting the progrefs of fermentation, fo that all domeftic proceffes of this kind are performed within doors, or near a fire, and in the large way chilling muft be particularly avoided; but as the act of fermentation produces a confiderable heat, the liquor within the veffel being feveral degrees warmer than the furrounding air, large maffes are of courfe lefs affected by the external cold, and will ferment at a lower temperature.

The firft figns of fermentation are, a gentle inteftine motion, the rifing of fmall bubbles to the top of the liquor, and a whitifh turbid appearance. This is foon followed by the collection of a froth, or head, confifting of a multitude of air-bubbles entangled in the liquor, which, as the procefs advances, rife flowly to a confiderable height, forming a white denfe permanent froth. A very large portion of the gas alfo efcapes, which has a ftrong, penetrating, agreeable, vinous odour. The temperature of the liquor at the fame time increafes to feveral degrees above that of the external air, and continues fo during the whole of the procefs.

Sooner or later these appearances gradually subside; the head of the foam settles into a dense froth, and on turning it aside, the liquor beneath appears much clearer and nearly at rest, having deposited a copious sediment, and from being viscid and saccharine is now become vinous, intoxicating, thinner, and of less specific gravity.

The process of fermentation, however, does not terminate suddenly, but goes off very gradually, the liquor continuing to work or throw up foam, to clarify, to attenuate, and more completely to lose its sugar, which at last can no longer be discerned by the taste, or detected by chemical analysis. The vinous liquor, when complete, if of sufficient strength and well fermented, will now keep for a great length of time in vessels secured from the air, and undergoes comparatively little farther alteration, except in becoming more perfectly limpid by the deposition of an additional quantity of sediment.

The gas of fermenting liquors has been long known to consist for the most part of carbonic acid; it will, therefore, extinguish a candle, destroy animal life, convert caustic alkalies into alkaline carbonats, and the like. But, beside the carbonic acid, it has been proved by Scheele to hold in solution a sensible quantity of alcohol, and Proust has detected in it a portion of azot. Mr. Collier (Manchest. Transf.) has further shewn that in this gas are contained all the requisites for vinous fermentation. He passed the whole of the gas from a ninety gallon fermenting tun into a cask of water, and divided the liquor thus impregnated into three parts, of which one being immediately distilled, afforded a small quantity of alcohol; to the second was added some yeast, by which a new fermentation was excited, and the subsequent product of distilled spirit was nearly doubled, and the third being suffered to ferment a longer time, produced some vinegar.

The attenuation of liquors, or the diminution of their specific gravity by fermentation, is very striking. This is shewn by the hydrometer, which swims much deeper in fermented liquor than in the same materials before fermentation. Much of this attenuation is, doubtless, owing to the destruction of the sugar, which, dissolved in water, adds to its density, and to the consequent production of alcohol, which, on the contrary, by mixture with water, diminishes the density of the compound. The extract, or mucilage, also appears to be in some degree destroyed by fermentation, for the gelatinous consistence of thick liquors is much lessened by this process: the destruction of this principle, however, is by no means so complete as of the sugar, many of the full-bodied ales, for example, retaining much of their original clamminess and gelatinous density even after having undergone a very perfect fermentation.

It has been doubted whether the alcohol of vinous liquors exists in them ready formed, or in some intermediate state, requiring the boiling heat of distillation for its complete developement. It is not easy to fix upon an unexceptionable mode of deciding this question. It has been argued by Fabbroni, in favour of alcohol being a product, and not an educt from wine, that wine cannot be again formed by adding the distilled alcohol to the residue left behind in the retort: he also affirms, that if a small portion of alcohol is added to wine, it may be separated again almost entirely by carbonat of potash, but that this salt will not separate any alcohol from wine in its natural state. This last fact, however, only shews that the union of the alcoholic with the other parts of the wine, is too strong to be broken by simple affinity, without the assistance of heat; and, as to the former, it is highly probable that the boiling heat operates some change on the other constituents of wine, the effect of which cannot be done away by the mere return of the spirit that has been driven off. This opinion, therefore, though by no means improbable, requires further confirmation.

The production of alcohol seems to be one of the last effects, or the completion of the process of fermentation; for if the liquor is distilled while yet in a state of high fermentation, it will not yield a drop of alcohol.

The atmospheric air seems to have no share whatever in vinous fermentation, for it will take place full as well inclosed as in open vessels, provided space is allowed for the great expansion of the materials, and the copious production of gas. Indeed Mr. Collier found, by direct experiment, that more spirit is procured by close than by open fermentation. In three separate experiments, in each of which an equal quantity of wort and yeast were fermented, under circumstances precisely similar, with the single exception, that in one the vessel was open, and in the other closed, (the gas having no exit but through a tube dipping in water,) he found, on distilling each fermented liquor, and drawing off the same bulk of spirit from each, that that from the close vessel was constantly of less specific gravity, and, therefore, richer in alcohol than the other. Where the spirit from the open vessel was 74 degrees below proof, that from the close vessel was 56 degrees; where the former was 83, the latter was 65; and where it was 103, the other was 93.

The theory of vinous fermentation is still involved in great difficulty, on account of the very compound nature of the substances employed, and their great tendency to decomposition in various ways and proportions.

The results of Lavoisier's experiments should not pass unnoticed, though it is obvious that much too great simplicity is attempted in the explanation of a process which every circumstance shews to be very complicated. The simple point to which the experiments of this able inquirer tend, is (setting aside all other agents) to explain how sugar becomes converted into carbonic acid and alcohol, which, after all, is the characteristic phenomenon of vinous fermentation.

The entire products of sugar, yeast, and water, fermented in close vessels, are stated to be carbonic acid, alcohol, and water, together with a small portion of acetous acid, and from these facts the following theory is deduced. Sugar is composed of eight parts hydrogen, 64 oxygen, and 28 carbon, and the process of fermentation effects a change merely in the arrangement of the constituent parts of the sugar, converting one portion into carbonic acid, and the other into alcohol; and hence (as carbonic acid contains only carbon, with a large proportion of oxygen) the portion which is left must contain all the hydrogen, part of the carbon, and a very small proportion of oxygen: or, in other words, by this new arrangement of the ingredients of the sugar, one portion, namely, the carbonic acid, is totally deprived of hydrogen, and overloaded with oxygen, while the other portion, namely, the alcohol, abounds in hydrogen, and is deficient in oxygen; the carbon being divided between the new products in nearly an equal proportion with regard to their respective quantities.

No theory more plausible than the above has, perhaps, hitherto been offered to the general phenomenon of vinous fermentation, though it is very defective in many essential parts, and even does not correspond with the alleged composition of alcohol, given by the same chemist in another part of his enquiries.

The great question remaining for future enquirers to determine is, what the substance or circumstance is, which disposes sugar to ferment; for it has been proved that sugar will not of itself begin this spontaneous change into carbonic

acid and alcohol; though, when once begun, the process will probably go on without further assistance.

It has been already mentioned, that both extractive matter and an acid are present in every known instance of vinous fermentation; and, for any thing that appears to the contrary, both of them are necessary, though the requisite quantity of each is very small compared to the sugar: therefore the strength or body of the fermented liquor is in direct proportion to the quantity of sugar alone, and there is good reason to suppose that the extractive matter and the acid are only accessary ingredients, though still essential, as being those without which the vinous decomposition of sugar cannot be effected.

It has been supposed that it is the *vegeto-animal* extract, as it has been called, which exists in the fermentable juices of vegetables, that causes the first change in the sugar. The precise nature of this vegeto-animal matter is not very well known: it may be supposed to be similar to the gluten of wheat, but intimately combined with the saccharine mucilage, and hence extremely susceptible of spontaneous change. The chief, if not the only, proof of its existence in many of these combinations, is the production of a quantity of ammonia during its decomposition by heat, which alkali is almost always *formed* by the action of fire, and indicates in the substance which yields it the presence of azot.

Some of the commonest fermenting ingredients, as the sweet infusion of malt, technically called wort, it is well known, will hardly enter into fermentation without the addition of *yeast;* and hence chemists have sought in this substance for the principle which gives the first impulse to the fermentation of sugar.

The analysis of yeast presents a vast variety of ingredients, the chief of which are the carbonic, acetic, and malic acids, mucilage, sugar, and gluten. Of these the latter is in the largest proportion, which would seem to give much weight to the opinion of the great share which the azotic ingredient has in inducing fermentation.

Yet Mr. Henry found by a series of very interesting experiments, that malt infusion might be made to enter into compleat fermentation by impregnating it with carbonic acid prepared from chalk and sulphuric acid, and the liquor thus fermented gave a yeast which made perfect bread, gave alcohol by distillation, and vinegar by further keeping. The wort itself undoubtedly contained all the ingredients of yeast, since this substance was produced during the fermentation, but the experiment is decisive to prove that no addition of azotic extract is required to begin fermentation in materials naturally fermentable, though, when once begun, the yeast, as fast as it was produced, must have assisted in the fermentation then going on. The evidence for the necessity of an acid to begin fermentation is therefore more decisive, but it is still doubtful whether any particular one is required, or whether there are not several which will answer the purpose. In Mr. Henry's experiments the acid employed was the carbonic, and, from the arrangement of the apparatus, probably a small portion of sulphuric was also carried in along with it. But in grape juice there is no proof of the existence of carbonic acid ready formed, though the tartaric, malic, and other vegetable acids contain within themselves the ingredients of carbonic acid, and are chiefly and ultimately resolvable into this acid. Yeast will even induce fermentation after it is pressed and dried into solid cakes, (a practice not uncommon, as it will keep for a great length of time in this form,) but after this operation it can hardly contain any carbonic acid ready formed, though with abundant tendency to produce it by the first mutual action of its constituent parts. Many interesting enquiries therefore remain to be carried on before we can have a full and satisfactory theory of the important process of vinous fermentation.

Fermentation, *Acetous*. See Acetous *Acid*, and Vinegar.

Fermentation, *Putrid*. See Putrefaction.

Fermentation, *Bituminous*, in *Geology*, denotes a particular change, which, according to the opinion of Mr. James Parkinson, (Organic Remains, vol. i. p. 184.) "is peculiar to vegetable matter placed in such situations, as not only exclude the external air, and secure the presence of moisture, but prevent the escape of the more volatile principles, and which terminates in the formation of those substances called bitumens." This author, after giving a concise, but luminous account of the *saccharine*, the *vinous*, the *acetic*, and the *putrid* fermentation, to which most vegetable substances are progressively liable, by the modified admission of atmospheric air, thus proceeds: "But if, instead of being thus exposed to the influence of the air, a mass of dead vegetable matter be accumulated in such situations as allow of the admission of water, but in which the compactness of the superincumbent stratum of earth, not only excludes the external air, but the disengaged gaseous matters are prevented from escaping, the bituminous fermentation takes place, and bituminous matters are formed in various degrees of maturity and pureness, according to the stage at which the process may have arrived, or the extraneous matters which may have been admitted." Our author, however, admits, that a complete history of all the phenomena which occur during the whole of the operation cannot possibly be expected to be made out, but the proofs of its existence must be obtained by inference, and from analogy on comparing it with the other species of fermentation; and he thus continues: "the substance, then, which I conceive to be entirely dependent on, and actually the product of, this process, is bitumen; a substance which manifests, upon examination, all those properties which might, *a priori*, be expected to be found in a body constituted under the particular circumstances which I have presumed to have directed its formation.

"In the first stage of the vinous fermentation, we perceive that a considerable portion of the more volatile parts of the mixture is dissipated, and that it is only by the careful preservation of the remainder that the accomplishment of this process is effected. In the acetous fermentation this escape of the volatile parts is continued through the whole of the process, and occasions the great difference which exists between the two products. In the first of these species of fermentation, carbon, that principle which always seems to affect that mode of combustion, observable in ignited charcoal, where flame is not present, is, we have remarked, dissipated in very large quantities, by which its dose in the mixture must be considerably diminished; whilst, should hydrogen even be supposed to escape in a similar proportion, still, from the decomposition of the water, sufficient of this principle (which I will call the principle of inflammability) will be yielded, to give the spirituous and very inflammable product which we find to be the result of this process. In the latter of these species of fermentations, in which the dissipation of the volatile matters is carried to the utmost extent which the degree of temperature will admit, the mixture seems to be deprived of almost the whole of its hydrogen; except, perhaps, just so much as is left in combination with the colouring principle, and the water, whilst the oxygen is attracted, nearly in the same proportion, by the carbon from the atmosphere, and from the very

confiderable dofe of this acidifying principle; and, from fome peculiar modification of their union, the product, *vinegar*, refults, poffeffing a high degree of acidity, but not the leaft degree of inflammability.

"We will now examine the changes which may be expected to refult from the decompofition of vegetable matters placed in fubterranean fituations, and confidering thefe, with the properties which are poffeffed by the fuppofed product of the bituminous fermentation, we fhall be enabled, efpecially by recollecting what has been juft faid of the other fpecies of fermentation, to determine whether it is right to admit of the exiftence of fuch a fpecies of fermentation or not.

"Secured on every fide by the furrounding earth, the mafs of vegetable matter is preferved, at it were, in a well-clofed veffel; hardly any efcape being permitted to any of its more volatile particles, nor any admiffion of extraneous matters allowed, except of fuch as are introduced with the water which may infinuate itfelf by foaking through the interftices of the earthy particles, compofing the feveral ftrata which inclofe it.

"It is decreed, that a ftrong difpofition to feparate, and to unite in another order, fhall fecure the neceffary decompofition of dead organized matter, which, according to the economy of nature, is but to poffefs a fhort and tranfient cohefion. Agreeable to this law, this mafs of vegetable matter, now deprived of the energy of vegetable life, muft undergo fome change; but from the clofenefs of its prefervation, it cannot admit that efcape of the gafeous matters on which the commencement of the vinous, acetous, or putrid fermentations depend: another procefs is therefore inftituted. The hydrogen, carbon, and oxygen are difengaged from their former attachments, but being prevented from flying off in a gafeous ftate, are obliged again to unite, and to enter into new combinations.

"Under thefe particular circumftances a fubftance may be expected to be formed, containing a confiderable portion of thefe principles fo abundant in vegetable matter. In this refpect, there undoubtedly may be difcovered a remarkable agreement between the fuppofed product of this fermentation, and the hypothefis by which its formation is attempted to be explained; fince, in all bituminous fubftances the abundant exiftence of thefe three principles has been fufficiently proved by analyfis.

"In this, as in every other fpecies of fermentation, a confiderable difference may exift, as to the degree of perfection to which the procefs may proceed, and of courfe, as to the degree of perfection which the product may poffefs.

"Thus I expect to fhew, that, according to length of time, exclufion from the air, and the exiftence of other favourable circumftances, will thefe bituminous fubftances be found in their feveral approaches to that ftate, to which the law of nature feems to have particularly deftined them.

"Peat, that combuftible and inflammable fubftance, generally found in confiderable maffes at a little depth beneath the furface of the earth, poffeffing chemical properties effentially different from every other fubftance which has not derived its exiftence from the fame origin, appears to be the firft product of this kind of fermentation, and to have been formed in fituations not favourable to the rapid completion of this procefs. The celerity with which this procefs is accomplifhed muft depend on the clofenefs with which the gafeous principles are fecured; but it fhould be confidered, that fuch peat-bogs as are, comparatively, but of modern formation, are covered by a coat of vegetable mould, in an humid ftate, of no confiderable degree of thicknefs, and therefore the efcape of the more volatile principles, and the admiffion of atmofpheric air, are only partially prevented; the procefs muft therefore be carried on with much lefs effect, than in thofe cafes which will be hereafter mentioned, where vaft maffes of vegetable matters have been fuddenly buried under a confiderable thicknefs of earthy depofition.

"The abundance of hydrogen, carbon, and oxygen, in peat, is demonftrated by its analyfis. By the early analyfis of Schoockius we learn, that it yields an oil much refembling the oil of amber, with an acid liquor. Monf. Fourcroy relates, that, on expofing peat to the action of heat in a diftillatory apparatus, a yellow or reddifh fœtid water is obtained, an oil of a moft difagreeable odour, with carbonate of ammonia, and carbonated hydrogen gas, alfo fmelling moft difagreeably; a coal being left, which is frequently pyrophoric, and which yields, after incineration, muriate and fulphate of foda and of pot-afh, mixed with the phofphate and fulphate of lime, and with the oxyds of iron and of manganefe.

"The prevalence of hydrogen in this fubftance is fully difplayed by the foregoing analyfis, fince not only enough exifts for the formation of this peculiar oil, but a confiderable quantity of this principle is alfo difengaged in a gafeous form; the agreement, therefore, between this fubftance, and what might, *a priori*, have been fuppofed, would be the product of a vegetable matter placed under thefe particular circumftances, appears to be evident. The original mode of exiftence which belonged to this fubftance is fufficiently marked by the great quantities of vegetable fubftances which are found in it, which have not fuffered fuch an alteration, as to hinder the immediately tracing them to their true origin. That this fubftance has been fubjected to the influence of the two circumftances, which feem effential to this peculiar fermentation, the prefence of moifture and fubterranean fituation, muft appear fo plain from the ftate in which the peat moffes are found, that, on this point, not a word need be added. Peat, therefore, I prefume, we may regard as a vegetable fecondary foffil; having been formed from vegetable matter, changed in its nature and properties by a certain fermentation, which had been carried on in the mineral regions."

The further profecution of this theory by our author, in order to account for the formation of amber, and jet, &c. are too long for our purpofe, but are well worthy the perufal of thofe who wifh to become acquainted fully with this fubject.

FERMENTATION, Vinous, in *Chemiftry*. The recent obfervations of chemifts enable us to ftate with greater precifion the changes which fugar undergoes during its converfion into alcohol, than could be done when this article was written for the Cyclopædia.

Sugar is compofed, according to Dr. Prout's analyfis, of

Hydrogen	- -	6.66
Carbon	- - -	40.00
Oxygen	- - -	53.33
		= 100.

which correfpond with 1 atom of each element.

Alcohol, according to Dr. Thomfon, is a compound of about

Hydrogen	- -	13.04
Carbon	- - -	52.16
Oxygen	- -	34.80
		100.

which correfpond with 3 atoms of hydrogen, 2 atoms of carbon, and 1 atom of oxygen; and carbonic acid gas is compofed of

Carbon - - -	27.27
Oxygen - - -	72.72
	100.

or of 1 atom of carbon and 2 atoms of oxygen.

Hence, if we fuppofe (for the fake of round numbers) 3 atoms of fugar to be decompofed during the procefs of fermentation, they will be converted into 1 atom of alcohol and 1 atom of carbonic acid; for

	Hydrogen.	Carbon.	Oxygen.
1 atom alcohol confifts of	3 atoms	+ 2 atoms	+ 1 atom
1 atom carbonic acid gas of		1 atom	+ 2 atoms
which make together		+ 3	+ 3

or three atoms of fugar.

Now this determination very nearly coincides with the actual experiments of Lavoifier, and the more recent determination of Thenard, refpecting the proportional quantities of thefe two products obtained by the fermentation of fugar. Thus 100 parts of fugar (as deduced by Dr. Thomfon from Thenard's experiments) were converted into

Alcohol - - -	57.44
Carbonic acid - -	42.56
	100.

Whereas the proportions, according to the above calculations, ought to have been

Alcohol - - -	51.12
Carbonic acid - -	48.88
	100.

A coincidence as near as could have been expected, confidering the very difficult nature of the experiment.

With refpect to the *modus operandi* of ferments, we have nothing to add, but that the fubject ftill remains a myftery. See Wine, and Yeast.

File

FILE, an inftrument ufed for reducing, and for giving fhape and fmoothnefs to a number of articles made of wood or metal.

It is divided into two varieties from the form of their teeth, namely, files and rafps. The former are cut upon the furface with a fharp-edged chiffel. In the latter, the tooth is raifed with a triangular punch. The file is adapted for working metals, but the rafp is more fitted for wood, bone and horn. Files again are diftinguifhed by being fingle or double cut. The fingle cut file is fimply cut once over, and is employed for filing brafs, and the fofter metals. A fecond courfe of teeth is cut to form the double cut file, croffing the firft diagonally. This kind is beft fuited to iron and fteel.

Files are alfo called by different names, from the various degrees of finenefs of their teeth, as fmooth, fecond cut, baftard cut, and rough files.

And again, from their fhape, they are called flat, half-round, fquare, three fquare, round, and fome having two round fides.

The fteel employed for files requires to be very hard, and in confequence undergoes a longer procefs in the converfion: it is faid to be double converted.

The very heavy files, fuch as fmiths' rubbers, are made of the inferior marks of bliftered fteel: the more delicate kind, fuch as watch-makers' files, being made of caft fteel. The fteel is previoufly drawn at the tilt, into rods of fuitable fize.

Forging of Files.—The flat and the fquare files are made wholly with the hammer, and the plain anvil. Two workmen, one called the maker, and the other ftriker, are required in the forging of heavy files; the fmaller being forged by one perfon only.

The anvil is provided with a gate, or groove, for the reception of certain boffes, or dies, which are ufed for the purpofe of forging the half-round and three-angled files. The half-round bofs contains a hollow which is the fegment of a fphere, much lefs than half a circle. That ufed for the triangular files has a gate or hollow, confifting of two fides, terminating in an angle at the bottom.

In forging the half-round file, the fteel is firft drawn out, as if intended to make a flat file. It is then laid in the bofs, and hammered, till the underfide becomes round. The fteel for the triangular file is tilted into fquare rods. The part to form the file is firft drawn out with the hammer, as if intended to form a fquare file. It is then placed in the bofs with one of the angles downwards, and by ftriking upon the oppofite angle, two fides of the fquare are formed into one, and confequently a three-fided figure produced. By fucceffively prefenting the different fides to the action of the hammer, the figure is rendered ftill more compleat.

In forming the tangs of moft files, it is neceffary to make the fhoulders perfectly fquare and fharp. This is performed by cutting into the file a little on each fide with a fharp fate or aggron, and afterwards drawing out the part fo marked off, to form the tang.

After forging, and previous to being ground and cut, the files require to be annealed. This procefs is generally performed by piling up a great quantity together, in a furnace for the purpofe, and heating them red hot; fuffering them afterwards to cool flowly. This method of annealing files, or indeed any other articles, in which great hardnefs is requifite, is very objectionable, fince the furface of fteel, when heated red hot in the open air, is fo liable to oxydation. Two evils refult from this circumftance, befides the lofs by wafte. Firft, the fcaly oxyd is very hard, and difficult to remove; and fecondly the fteel, particularly on the furface, is deprived of a portion of its carbon, and thereby rendered lefs fufceptible of hardening.

A fuperior method of annealing is practifed by fome file makers, and fince hardnefs in a file is fo effential a property, the procefs ought to be generally adopted.

This method confifts in placing the files in an oven or trough, having a clofe cover, and filling up the interftices with fand. The fire is made to play on every fide of this veffel, as gradually, and as uniformly as poffible, till the whole mafs becomes heated red hot. The fire is then difcontinued, and the whole fuffered to cool, before the cover is removed from the trough. Another evil may however arife from keeping fteel red hot even in a clofe veffel, for too great a length of time. It affumes a kind of cryftallization under which its tenacity is much impaired. Hence, it will be proper not to anneal too many at once, and not to heat them too hot. Steel, annealed in this way, is perfectly free from that fcaly furface acquired in the open air; and if each corticle be perfectly furrounded with the fand, and the cover not removed before the fteel is cold, the furface will appear of a filvery white colour.

If the fteel be fufpected to be too kind, from containing too little carbon, powdered charcoal may be employed inftead of fand, or fand mixed with charcoal. In this cafe the files fhould be ftratified alternately with the charcoal, in order that the extra-converfion may be uniform.

The next thing is to prepare the files for cutting, by making the furface, to contain the teeth, as level as poffible. This was formerly effected by means of files; and the procefs is called ftriping. The fame is ftill practifed by the Lancafhire file makers, and by others not having convenience for grinding. The greateft quantity of files, however, are ground to prepare them for cutting. The ftone employed for the purpofe is of the fandftone kind, the texture of which is compact and fharp, but rather rough. They are of as great diameter as can be ufed with convenience; and about eight inches broad over the face. When ufed, the furface is kept immerfed in water. The grinder fits in fuch a pofition as to lean over the ftone, while its motion is directly from him. Its furface moves at about the fame fpeed with thofe ufed in grinding cutlery. Since the object in grinding files is to make the furface as even and flat as poffible, and as this cannot be done fo completely upon a fmall ftone, the ftones of the file-grinder are laid afide when they are reduced to a certain fize, and are employed for

grinding other articles. Though grinding is by far the most expeditious method, it does not give that truth to the surface which can be effected by filing. If the price of the articles would admit, however, it would be well to render the surface more even by the file after grinding. If the surface be not flat, it is obvious, that when the file is used for filing a large surface, those teeth in the hollow parts of the file will not be brought into action. It is from attention to this circumstance, and to the care in annealing and hardening, that the Lancashire file-makers have generally excelled. They are, however, confined chiefly to the small articles, since the larger files would not pay for the process of striping.

Cutting of Files.—If the vast number of teeth contained in a file, and their requisite uniformity are considered, a machine capable of effecting a business so apparently mechanical, may be considered a desideratum.

Though many attempts have been made to accomplish this object by machinery, and several varieties of machines have been constructed for the purpose, no one has yet been sufficiently general in its application, to render the prosecution of such an object very desireable. Among those who have distinguished themselves in this enquiry, Mr. Nicholson, the publisher of the Philosophical Journal, we believe, invented the most likely machine for file cutting, for which he took out a patent. We do not know, however, that either Mr. Nicholson's, or any other machine, is at present used for the purpose. A file, which is of the same breadth and thickness throughout, of any form, may be cut by the machine, because the same magnitude of stroke is required for every tooth; but if the file be conical, it is obvious that a machine, capable of giving all the varieties of strokes required in cutting even one side of a file, would be too complicated to be of any great utility. Again, the chissel employed for cutting a file is frequently liable to snip, or be otherwise out of order. This the workman, in the common way of cutting, can easily feel, and immediately stops to repair it. A very great evil would arise from this source, in cutting with the machine; and this evil would be greater in proportion to the number of chissels which one person had to overlook. It has also been said, but we cannot affirm the fact, that the teeth raised by machinery are not so full and sharp as those formed by hand. Till the above inconveniences can be obviated, in all probability the common method will be continued; the different apparatus and mode of performance of which we will endeavour to describe.

The tools of the file-cutter consist of an anvil placed upon a block of such a height, that the man sits to his work. He has also a piece of lead, or lead alloyed with tin, on which he lays the files when one side is cut. The chissel and hammer are of such size, as the size and cut of the file require. He is also provided with a leather strap, which goes over each end of the file, and passes round his feet, which are introduced into the strap on each side, in the same manner as stirrups are used. The file-cutter, therefore, sits as if he were on horseback, holding his chissel with one hand, his hammer in the other, at the same time he secures the file in its place by the pressure of his feet in the stirrups. A, *fig.* 1. (*Plate* XIII. *Miscellany,*) is the block; B, the anvil; *a b*, the file, laid upon the piece of lead; C, C, the stirrups passing over the ends of the file; D, the seat on which the workman sits. *Fig.* 2. is the form of one of the chissels for cutting the files. *Fig.* 3. represents the chissel or punch for raising the tooth of the rasp. *Fig.* 4. the hammer used to strike the head of the chissel. These people have found by experience that there is an advantage in having the head of the hammer hooked inwards. This is easily accounted for, when we observe that the stroke will be made pretty near the centre of percussion. Great pains ought to be taken in preparing the edge of the chissel. It is, in the first place, hardened and tempered by heating it gradually till it appears of a yellowish brown. It is next ground very true to form the edge, which is afterwards finished upon a Turkey stone, with oil. It is not required to be very sharp, the bottom of the tooth requiring to be rather open, to prevent the file from clogging with the substance to be filed. The edge is also required to be very smooth, in order that it may slip easily upon the surface of the files: this is also facilitated by slightly greasing the surface. From this advantage, the worker, after making one tooth, is enabled, by feeling only, to form, at its proper distance, the succeeding tooth, by sliding the chissel close up against the back of the preceding one. All these motions are performed with astonishing rapidity, first the chissel and then the hammer. We observed a boy, in cutting three-sided files of five inches long, bastard cut, make 225 strokes, which produced as many teeth, in one minute. And the whole file being double-cut, contained 1350 teeth, or six times the above quantity. The second cut file, of the same size, contains 2025 teeth, and the smooth file 2700, consequently, the difference in labour between the bastard-cut and the smooth files is about as two to one. Larger files, from the greater surface, require a much greater stroke to raise the tooth, and consequently fewer strokes will be made in the same time.

In the double-cut files, the first set of teeth, which the workmen call *up-cutting*, are, previous to cutting the second course, filed slightly upon the face, in order to allow the chissel to slide freely.

The single-cut file is more durable than the double-cut, and ought to be preferred for all purposes, excepting for iron and steel.

The same method is employed in cutting the rasp. The workman is however guided completely by his eye, in regulating the distance of the teeth from each other. The rasp ought to be cut in such a manner that no one of the teeth may stand opposite to another. This not only allows the rasp to cut faster, but makes the surface, either of wood or other substance, much smoother.

Hardening of Files.—This is the last and most important part of file-making. Whatever may be the quality of the steel, or however excellent the workmanship, if it is not well hardened, all the labour is lost.

Three things are strictly to be observed in hardening; first, to prepare the file on the surface, so as to prevent it from being oxydated by the atmosphere, when the file is red hot, which effect would not only take off the sharpness of the tooth, but render the whole surface so rough, that the file would, in a little time, become clogged with the substance it had to work. Secondly, the heat ought to be very uniformly red throughout, and the water in which it is quenched fresh and cold, for the purpose of giving it the proper degree of hardness. Lastly, the manner of immersion is of great importance, to prevent the files from warping, which in long thin files is very difficult.

The first object is accomplished by laying a substance upon the surface, which, when it fuses, forms as it were a varnish upon the surface, defending the metal from the action of the oxygen of the air. Formerly, the process consisted in first coating the surface of the file with ale grounds, and then covering it over with pulverized common salt, (muriat of soda.) After this coating became dry, the files are heated red hot, and hardened; after this, the surface is lightly brushed over with the dust of cokes, when it appears white and metallic, as if it had not been heated. This process has

lately been improved, at leaſt ſo far as relates to the economy of the ſalt, which, from the quantity uſed, and the increaſe of duty, had become a ſerious object. Thoſe who uſe the improved method are now conſuming about one-fourth the quantity of ſalt uſed in the old method. The proceſs conſiſts in diſſolving the ſalt in water to ſaturation, which is about three pounds to the gallon, and ſtiffening it with ale grounds, or with the cheapeſt kind of flour, ſuch as that of beans, to about the conſiſtence of thick cream. The files only require to be dipped into this ſubſtance, and immediately heated and hardened. The grounds, or the flour are of no other uſe, than to give the maſs conſiſtence, and by that means, allowing a larger quantity of ſalt to be laid upon the ſurface. In this method, the ſalt forms immediately a firm coating. As ſoon as the water is evaporated, the whole of it becomes fuſed upon the file. In the old method the dry ſalt was ſo looſely attached to the file, that the greateſt part of it was rubbed off into the fire, and was ſublimed up the chimney, without producing any effect.

The carbonaceous matter of the ale-grounds is ſuppoſed to have ſome effect, in giving hardneſs to the file, by combining with the ſteel, and rendering it more highly carbonated. It will be found, however, upon experiment, that vegetable carbon does not combine with iron, with ſufficient facility, to produce any effect, in the ſhort ſpace of time a file is heating, for the purpoſe of hardening. Some file makers are in the habit of uſing the coal of burnt leather, which doubtleſs produces ſome effect; but the carbon is generally ſo ill prepared for the purpoſe, and the time of its operation ſo ſhort, as to render the effect very little. Animal carbon, when properly prepared and mixed, with the above hardening compoſition, is capable of giving hardneſs to the ſurface even of an iron file.

The carbonaceous matter may be readily obtained from any of the ſoft parts of animals, or from blood. For this purpoſe, however, the refuſe of ſhoe-makers and curriers, is the moſt convenient. After the volatile parts have been diſtilled over, from an iron ſtill, a bright ſhining coal is left behind, which, when reduced to powder, is fit to mix with the ſalt. Let about equal parts, by bulk, of this powder, and muriat of ſoda, be mixed together, and brought to the conſiſtence of cream, by the addition of water. Or mix the powdered carbon with a ſaturated ſolution of the ſalt, till it become of the above conſiſtence. Files which are intended to be very hard, ſhould be covered with this compoſition, previous to hardening. All files intended to file iron or ſteel, particularly ſaw files, ſhould be hardened with this compoſition in preference to that with the flour or grounds. Indeed, we are of opinion, that the carbonaceous powder might be uſed, altogether, in point of economy, ſince the ammonia or hartſhorn, obtained by diſtillation, would be of ſuch value as to render the coal of no expence. By means of this method the files made of iron, which in itſelf is inſuſceptible of hardening, acquires a ſuperficial hardneſs, ſufficient for any file whatever. Such files may at the ſame time be bent into any form, and, in conſequence, are particularly uſeful for ſculptors and die ſinkers.

The next point to be conſidered is the beſt method of heating the file for hardening. For this purpoſe a fire, ſimilar to the common ſmiths' fire, is generally employed. The file is held in a pair of tongs, by the tang, and introduced into the fire, conſiſting of very ſmall cokes; puſhing it more or leſs into the fire for the purpoſe of heating it regularly. It muſt frequently be withdrawn for the purpoſe of obſerving, that it is not too hot in any part. When it is uniformly heated, from the tang to the point, of a cherry red colour, it is fit to quench in the water. At preſent an oven, formed of fire bricks, is uſed for the larger files, into which the blaſt of the bellows is directed, being open at one end, for the purpoſe of introducing the files and the fuel. Near to the top of the oven are placed two croſs bars, on which a few files are placed, to be partially heating. In the hardening of heavy files, this contrivance affords a conſiderable ſaving, in point of time, in addition to which they are more uniformly and thoroughly heated.

After the file is properly heated for the purpoſe of hardening, in order to produce the greateſt poſſible hardneſs, it ſhould be cooled as ſoon as poſſible. The moſt common method of effecting this is by quenching it in the coldeſt water. Some file makers have been in the habit of putting different ſubſtances in their water, with a view to increaſe its hardening property. The addition of the ſulphuric acid to the water was long held a great ſecret in the hardening of ſaw files. After all, however, it will be found, that clear ſpring water, free from animal and vegetable matter, and as cold as poſſible, is the beſt calculated for hardening files of every deſcription.

In quenching the files in water ſome caution muſt be obſerved. All files, except the half round, ſhould be immerſed, perpendicularly, as ſlowly as poſſible, ſo that the upper part ſhall not cool. This management prevents the file from warping. The half round file muſt be quenched in the ſame ſteady manner, but at the ſame time it is kept perpendicular to the ſurface of the water, it muſt be moved a little horizontally, in the direction of the round ſide, otherwiſe it will become crooked backwards.

When the files are hardened, they are bruſhed over with water and powdered cokes, when the ſurface becomes perfectly clean and metallic. They ought, alſo, to be waſhed well, in two or three clean waters, for the purpoſe of carrying off all the ſalt, which, if remaining, will be liable to ruſt the file. In addition to this, they ſhould be dipped into lime water, and rapidly dried before the fire, after being oiled, with olive oil, containing a little oil of turpentine, while ſtill warm, and they are deemed finiſhed.

Filing

FILING, in *Mechanics*, is the operation of uſing a file in cutting away and reducing various ſubſtances into any required form. The file is chiefly confined to the working of metal, though it is occaſionally applied to wood, ivory, bone, &c. The art of filing is an eſſential to every workman in metal, and it requires great practice and ſkill to perform it well: the principal difficulty conſiſts in filing a truly plane and even ſurface to any piece of metal. To do this, the work muſt be held firmly in a vice, ſo that the ſurface to be filed be truly horizontal; the workman then files it over with a file, adapted in its cut, or ſize of its teeth, to the magnitude of his work: in doing this, if it is large, he takes one end of the file in each hand, holding it firmly, as he moves it backwards and forwards, in a horizontal plane, taking care not to lean heavier upon one end of the file than the other. The file only cuts in going forwards; he muſt therefore preſs harder upon it, that it may take hold of the metal: in drawing it back it is unneceſſary to lean on the file, becauſe it is not then adapted to act; it is uſual, in filing a piece of flat work, to begin at one ſide, and every time the file is drawn back, to move it ſideways at the ſame time about the breadth of the file: the next ſtroke proceeds ſtraight forwards, as before, but in a freſh place, unleſs ſome ſudden eminence is to be reduced; then two or more ſtrokes ſhould be made in one place, or the preſſure on the file increaſed till all is brought to a flat or even ſurface. When the whole of the work has been done over in one direction, it is then filed in the ſame manner at right angles thereto, and afterwards diagonally, till it is finiſhed, trying it occaſionally by a ſtraight edged ruler. Some workmen, by long practice and experience, are able to make the work flat by filing in one direction only, and without any trial; ſo that if two ſurfaces of metal thus filed are placed one upon the other, they will adhere together for an inſtant if the upper one be ſuddenly lifted up. The height of the vice, in which the work is held, is a matter of ſome importance in filing; if the work is large, it ſhould be about forty inches above the floor on which the workman ſtands; for ſmall work it may be higher, becauſe the workman does not need to bear ſo heavily on the work. In filing articles which are to be fitted together, the workman makes uſe of beviles, guages, rulers, compaſſes, &c. to mark out and try the work. Round pins, &c. are held in a hand-vice, and ſupported on a piece of wood while they are filed, and the workman turns them round while he files, in order that they may be truly round and have no angles.

The file-makers in Lancaſhire, for cutting the teeth of their ſmall files, ſometimes make uſe of a knife, *fig.* 5. *Plate* XIII. *Miſcellany*, which has a beviled edge; the workman uſes it in the ſame manner as the chiſſel, except that no hammer is employed. The fineſt files uſed by watch-makers have ſometimes as many as 350 teeth *per* inch, which are frequently cut by the knife; other watch-makers' files are cut in the manner above deſcribed, by the chiſſel, *fig.* 6, which is ſtruck on the head by a ſmall hammer. The ſmalleſt chiſſels uſed are not a vaſt deal larger than the figure, and the hammer, *fig.* 7, is the full ſize, though the handle in reality is ſomewhat longer; ſome of very fine watchmakers' files are not larger than needles, and are called needle-files.

Fire-engine

FIRE-*engine*, is a machine for extinguiſhing accidental fires by means of a ſtream or jet of water. The common ſquirting fire-engine conſiſts of a lifting pump placed in a circular or cylindric veſſel of water, and wrought by two levers that act always together. During the ſtroke, the quantity of water raiſed by the piſton of the pump ſpouts with force through a pipe joined to the pump-barrel, and made capable of any degree of elevation by means of a yielding leather pipe, or by a ball and ſocket turning every way, ſcrewed on the top of the pump. The veſſel containing the water is covered with a ſtrainer, which prevents the dirt and filth poured into it with the water from choaking the pump-work. Between the ſtrokes of this engine the ſtream is diſcontinued for want of an air-veſſel. However, in ſome caſes, engines of this conſtruction have their uſe, becauſe the ſtream, though interrupted, is much ſmarter than when the engine is made to throw water in a continued ſtream. The beſt engine of this latter kind is that of Mr. Newſham, formerly an engine-maker in London. A perſpective view of the whole engine, ready for working, is repreſented in *Plate* III. *Hydraulics*, &c. *fig.* 4. This engine conſiſts of a ciſtern A B, about three times as long as it is broad, made of thick oaken planks, the joints of which are lined with ſheet-copper, and eaſily moveable by means of a pole and croſs bar C in the fore part of the engine, which is ſo contrived as to ſlide back under the cover of the ciſtern, and on four ſolid wheels, two of which are ſeen at D and E. The hind axle-tree, to which the wheel E and its oppoſite are fixed, are faſtened acroſs under the bottom of the ciſtern; but the fore axle-tree, bearing the wheel D, &c. is put on a ſtrong pin or bolt, ſtrongly faſtened in a horizontal ſituation in the middle of the front of the bottom of the ciſtern, by which contrivance the two fore wheels and the axle tree have a circular motion round the bolt, ſo that the engine may ſtand as firm on rough or ſloping ground as if it was level. Upon the ground next to the hind part of the engine may be ſeen a leathern pipe F, one end of which may be ſcrewed on and off upon occaſion to a braſs cock at the lower end of the ciſtern: the other end is immerſed in the water, ſupplied by a pond, fire-plug, &c. and the pipe becomes a ſucking pipe for fur-

nifhing the pumps of the engine by its working, without pouring water into the ciftern. To the hind part of the ciftern is faftened a wooden trough G, with a copper grate for keeping out ftones, fand, and dirt, through which the ciftern is fupplied with water when the fucking pipe cannot be ufed. The fore part of the ciftern is alfo feparated from the reft of its cavity by another copper grate, through which water may be poured into the ciftern. Thofe that work the pumps of this engine move the handles vifible at the long fides, up and down, and are affifted by others who ftand on two fufpended treddles, throwing their weight alternately on each of them, and keeping themfelves fteady by taking hold of two round horizontal rails, H, I, framed into four vertical ftands, which reach to the bottom of the ciftern, and are well fecured to its fides. Over the hind trough there is an iron handle or key K, ferving to open or fhut a cock placed under it on the bottom of the ciftern, the ufe of which we fhall explain in the fequel of this article. L is an inverted pyramidal box or cafe which preferves the pumps and air veffels from damage, and alfo fupports a wooden frame M, on which ftands a man, who, by raifing or depreffing, and turning about the fpout N, directs the ftream of water as occafion requires. This fpout is made of two pieces of brafs pipe, each of which has an elbow; the lower is fcrewed over the upper end T (fee *fig.* 5.) of the pipe that goes through the air-veffel, and the upper part fcrews on to the lower by a fcrew of feveral threads, fo truly turned as to be water-tight in every fituation. The conic form of the fpouting-pipe ferves for wire-drawing the water in its paffage through it, which occafions a friction that produces fuch a velocity of the jet as to render it capable of breaking windows, &c. whilft the valves and leathern pipes of the engines have fufficient water-way to fupply the jet in its greateft velocity. Leather pipes of confiderable length may be fcrewed at one end of the nofel of the engine, and furnifhed at the other end with a wooden or brafs pipe for guiding the water into the inner apartments of houfes, &c. Between the pyramidal box L, and the fore end of the engine, there is a ftrong iron bar O, lying in an horizontal pofition over the middle of the ciftern, and playing in braffes fupported by two wooden ftands; one of which, P, is placed between the two fore-ftands of the upper rails, and the other is hid in the inclofure over the hind part. Upon proper fquares of this bar are fitted, one near each end, two ftrong crofs bars, which take hold of the long wooden cylindrical handles, by means of which the engine is worked; and the treddles by which they are affifted are fufpended at each end by chains in the form of a watch chain, and receive their motion jointly with the handles that are on the fame fide, by means of two circular fectors of iron faftened together, and fixed upon proper fquares of the middle horizontal bar; the two fore ones may be feen at Q; the two hind ones reprefented on a large fcale in *fig.* 6. differ from the former only in thicknefs; for the fore fectors are made to carry only one chain each, faftened by one end to their upper part, and by the lower end to the treddles; whereas the fole of the two hind fectors is wide enough to carry two chains each; one fet faftened like thofe of the fore ones for the motion of the treddles; and the other two chains are faftened by their lower ends to the lower part of thefe fectors, and by their upper ends to the top of the pifton bars, in order to give them motion. See *fig.* 6. in which the hind fectors and their apparatus are reprefented as they would appear to a perfon ftanding between the two fore-wheels, and looking at the hind part of the engine. The fquare over the letter A is the fection of the middle bar, on which, right over the two barrels, are placed the two fectors B C A and D E A, forged together. E G H K and *f g h k* are the two pifton rods; and the openings between the letters G, H, and *g*, *h*, are the fpaces through which the hind parts of the two treddles pafs. L and M reprefent two ftrong ftuds rivetted on the other fide of the bars on which they are placed; and to each of thefe is faftened a chain like a watch-chain, fixed by their upper ends to the upper extremities D and B of the iron fectors, by which they are drawn up and down alternately. Thefe fectors give alfo an alternate motion up and down to the pifton-rods, by means of two other chains left white in the figure, in order to diftinguifh them from the others: thefe are faftened by their lower ends to the lower extremities of the fectors E and C, and their upper ends terminating in a male fcrew, are made tight to the pifton-rods at I and *f*, by two nuts. The fhape of the pifton-rods, and the fize and fituation of the chains that give them motion, are fo contrived, that the vertical axis of the piftons is exactly in the middle of the breadth of the perpendicular part of the chains, and the upper part of the pifton-rod taken together. P Q reprefents one of the two crofs bars through the ends of which pafs the long handles to which the men apply their hands when they work the engine; thefe crofs bars are fitted on the middle bar at fome diftance from the fectors.

The other parts of this ufeful engine may be underftood by the help of *fig.* 5. which reprefents a vertical fection taken through the middle line of the hind part of the engine, as alfo the fection of the air-veffel, and that of one of the barrels, and likewife the profiles of the hind fectors, and of feveral other parts. A B is the fection of the bottom of the ciftern, and C that of the hindmoft axletree. D E is the vertical fection of a ftrong piece of caft brafs or hard metal, fo worked as to have a hollow in it, reprefented by the white part, and fixed to the bottom of the ciftern: this reaches from the opening D through the cock W, and afterwards divides itfelf into two branches, fo as to open under the two barrels; one of thefe branches is exhibited in the figure, and the other is exactly behind this. Through this channel, which may be called the fucking-piece, water is conveyed to the pumps by the preffure of the atmofphere, either from the ciftern itfelf, or from any place at a diftance, by means of a leathern pipe F, *fig.* 7, which fcrews on to the fucking-piece at D, *fig.* 5, under the hind trough Z, the grate of which is reprefented by the horizontal ftrokes. F G reprefents the vertical fection of another piece of caft brafs or hard metal that may be called the communication-piece, having two hollows for conveying the water from under the two piftons to the two openings of the flanch of the air-veffel; one of thefe hollows appears in the figure; the other lies exactly behind this, though not in a parallel direction. Between the fection of the fucking-piece D E, and that of the communication-piece F G, may be obferved the fection of one of the plates of leather, which makes all tight, and forms one of the two fucking valves, of which there is another juft behind this under the other barrel. R S T is the fection of the copper air-veffel, and T V that of the conduit-pipe; this veffel is fcrewed on to the hind part of the communication-piece, and at top is faftened by a collar of iron to a crofs piece of timber. Between the flanch of the air-veffel and the communication-piece may be obferved the fection of one of the plates of leather, making all tight, and fcrewing one of the two forcing valves, of which there is another juft behind this, exactly over the other opening of the communication from the air-veffel. Thefe valves are loaded

with a lump of caſt iron or lead, having a tail or teat let through the flap of the valve and croſs-pinned under it; and it is to be obſerved, tnat though both the valves are repreſented open in the figure, they are never both open at the ſame time; for when the engine is not at work they are cloſed down by the weights on their upper ſurfaces; and when the engine works, two are ſhut, and the other two are open alternately by the motion of the piſtons and the action of the atmoſphere, together with the re-action of tne air contained in the air-veſſel. H I is the ſection of one of the barrels of the two pumps, which are both ſucking and forcing, as is evident from the poſition of the valves and the ſtructure of the piſtons, each of which is compoſed of two iron plates, of two wooden trenchers, and of two flat pieces of leather turning one up and the other down. L K repreſents one of the piſton-rods edge-wiſe, behind which is one of the chains, the top ſcrew of which, K, can only be ſeen. M is the end of the middle bar, and N a ſection of the hindmoſt of the two middle ſtands which ſupport the middle bar. O repreſents the end of the profile of one of the treddles, paſſing through the rectangular holes of the piſton-rods, as in *fig.* 8. The weight on theſe treddles brings them and the piſton-rods down alternately, and they are raiſed up again by help of the other ſet of chains, one of which may be ſeen edge-wiſe in this figure, placed on the ſole of one of the ſectors, &c. See *fig.* 6.

P Q is part of the croſs bars which carry the handles ſeen edge-wiſe, and X Y repreſents an iron handle, by the help of which the cock W may be placed in the ſeveral ſituations requiſite for the uſe of the engine. The mechaniſm of the cock W may be underſtood by *figs.* 9, 10, and 11, which repreſent the horizontal ſection of it in three different ſituations. It has three holes that are left white in theſe figures. In *fig.* 9. the poſition of the cock is repreſented when the handle X Y or K is in a direction parallel to D E, or to the middle bar, as in *fig.* 5. and *fig.* 4. In this poſition, the water ſupplied by the ſucking-piece enters at D, and proceeds directly through the cock W to the valve under the two piſtons; and there is now no communication from the barrels with the cavity of the ciſtern. In *fig.* 10. we have the poſition of the cock when the handle X Y is turned one quarter of a revolution towards the eye from the laſt mentioned ſituation, in which caſe there is no communication from the barrels with the outer extremity of the ſucking-piece, but the water poured into the fore and hind trough, and paſſing from thence into the cavity of the ciſtern, enters the cock ſide-wiſe at W, and, turning at right angles through the cock towards E, proceeds to the barrels of the pumps. *Fig.* 11. repreſents the cock W when the handle is placed diametrically oppoſite to its laſt ſituation, in which caſe there is no communication from the under-ſide of the barrels with the cavity of the ciſtern or the outward end of the ſucking-piece; but this ſituation affords a communication from the cavity of the ciſtern with the outſide of the engine, and the water left in the cavity of the ciſtern may by this means be employed when the engine has done working. Theſe engines are made of five or ſix different ſizes. See Deſaguliers's Courſe of Exper. Philoſ. vol. ii. p. 505—518.

The principles on which this engine acts, ſo as to produce a continued ſtream, are obvious; the water, being driven into the air-veſſel, as in the operation of common ſucking and forcing pumps, will compreſs the air contained in it, and proportionably increaſe its ſpring, ſince the force of the air's ſpring will always be inverſely as the ſpace which it poſſeſſes; therefore, when the air-veſſel is half filled with water, the ſpring of the included air, which in its original ſtate counterbalanced the preſſure of the atmoſphere, being now compreſſed into half the ſpace, will be equal to twice the preſſure of the atmoſphere; and by its action on the ſubjacent water will cauſe it to riſe through the conduit-pipe, and to play a jet of 32 or 33 feet high, abating the effect of friction. When the air-veſſel is two-thirds full of water, the ſpace which the air occupies is only one-third of its firſt ſpace; therefore its ſpring being three times as great as that of the common air, will project the water with twice the force of the atmoſphere, or to the height of 64 or 66 feet. In the ſame manner, when the air-veſſel is three-fourths full of water, the air will be compreſſed into one-fourth of its original ſpace, and cauſe the water to aſcend in air with the force of three atmoſpheres, or to the height of 96 or 99 feet, &c. as in the following table:

Height of the water.	Height of the compreſſed air.	Proportion of the air's ſpring.	Height to which the water will riſe.
$\frac{1}{2}$	$\frac{1}{2}$	2	33 feet
$\frac{2}{3}$	$\frac{1}{3}$	3	66
$\frac{3}{4}$	$\frac{1}{4}$	4	99
$\frac{4}{5}$	$\frac{1}{5}$	5	132
$\frac{5}{6}$	$\frac{1}{6}$	6	165
$\frac{6}{7}$	$\frac{1}{7}$	7	198
$\frac{7}{8}$	$\frac{1}{8}$	8	231
$\frac{8}{9}$	$\frac{1}{9}$	9	264
$\frac{9}{10}$	$\frac{1}{10}$	10	297

See Martin's Philoſ. Brit. vol. ii. p. 69, &c.

The fire engine, by Rowntree, is a double-force pump, of a peculiar conſtruction, ſimilar in its action to the *beer-engine*, but as it is on a much larger ſcale, its conſtructions are of courſe varied. In this engine, *figs.* 1. and 2. *Plate* IV. *Hydraulics*, are two elevations at right angles to each other, of the external part of the engine mounted on four wheels. *Figs.* 3. and 4. are two ſections perpendicular to each other, of the body of the engine or pump; *figs.* 5. and 6. are parts of the engine. The ſame letters are uſed as far as they apply in all the figures, A, A, A, A; *fig.* 3. and 4. is a caſt-iron cylinder truly bored, ten inches diameter and fifteen long, and having a flanch at each end whereon to ſcrew two covers, with ſtuffing boxes, *a*, *a*, in their centres, through which the ſpindle, B, B, of the engine paſſes, and being tight packed with hemp round the collar, makes a tight joint; the piſton, D, is affixed to the ſpindle within the cylinder, and fits it tight all round by means of leathers; at E, *fig.* 4. a partition, called a ſaddle, is fixed in the cylinder, and fits againſt the back of the ſpindle tight by a leather.

We have now a cylinder divided by the ſaddle, E, and piſton, into two parts, whoſe capacity can be increaſed and diminiſhed by moving the piſton, with proper paſſages and valves to bring and convey away the water: this will form a pump. Theſe paſſages are caſt in one piece with the cylinder: one, *d*, for bringing the water is ſquare, and extends about $\frac{1}{3}$d round the cylinder; it connects at bottom with a pipe, *e*; at its two upper ends it opens into two large chambers, *f*, *g*, extending near the whole length of the cylinder, and cloſed by covers, *h*, *h*, ſcrewed on; *i*, *k*, are ſquare openings (ſhewn by dotted ſquares in *fig.* 3,) in the cylinder communicating with the chambers: *fg*, *lm*, are two valves, cloſing their ends of the curved paſſage, *d*, and preventing any

water returning down the passage, *d*; *n*, *o*, are two passages from the top of the cylinder to convey away the water; they come out in the top of the cylinder, which, together with the top of the chambers, *f*, *g*, form a large flat surface, and are covered by two valves, *p*, *q*, to retain the water which has passed through them. A chamber, K, is screwed over these valves, and has the air-vessel, *k*, *figs.* 1. and 2. screwed into its top; from each side of this chamber a pipe, *w w*, proceeds, to which a hose is screwed, as shewn in *fig.* 1. Levers, *x*, *x*, are fixed to the spindle at each end, as shewn in *fig.* 1, and carry the handles, H, H, by which men work the engine. When the piston moves, as shewn by the arrow in *fig.* 4. it produces a vacuum in chamber, *f*, and that part of the cylinder contiguous to it; the water in the pipe, *e*, then opens the valve, *m*, and fills the cylinder. The same motion forces the water contained in the other part of the cylinder through the valve, *q*, into chamber, K, and thence to the hose through the pipe, *w*; the piston being turned the other way, reverses the operation with respect to the valves, though it continues the same in itself. The pipe, *e*, is screwed by a flaunch to an upright pipe, P, *fig.* 5. connected with another square iron pipe, fastened along the bottom of the chest of the engine; a curved brass tube, G, comes from this pipe through the end of the chest, and is cut into a screw to fit on the suction hose when it can be used; at other times a close cap is screwed on, and another brass cap at H, within the chest, is screwed upwards on its socket, to open several small holes made in it, and allow the water to enter into the pipe; in this case the engine chest must be kept full of water by buckets. The valves are made of brass, and turn upon hinges. The principal advantage of the engine is the facility with which it is cleaned from any sand, gravel, or other obstructions, which a fire-engine will always gather when at work.

The chambers, *f*, *g*, being so large, allow sufficient room to lodge a greater quantity of dirt than is likely to be accumulated in the use of the engine at any one fire, and if any of it accidentally falls into the cylinder, it is gently lifted out again into the chambers by the piston, without being any obstruction to its motion: to clear the engine from the dirt, two circular plates, *r*, *r*, five inches diameter, are unscrewed from the lids, *h*, *h*, of the chambers, *f*, *g*, and when cleaned are screwed on again: these screw covers fit perfectly tight without leather, and can be taken out, the engine cleared, and enclosed again in a very short time, even when the engine is in use, if found necessary.

The two upper valves, *p*, *q*, and chamber, K, can also be cleared with equal ease, by screwing out the air-vessel, *k k*, *fig.* 1. which opens an aperture of five inches, and fits air-tight, without leather, when closed. The valves may be repaired through the same openings. The use of the air-vessel, *k k*, *figs.* 1. and 2. is to equalize the jet from the engine during the short intermittance of motion at the return of the piston stroke; this it does by the elasticity of the compressed air within it, which forces the water out continually, though not supplied quite regularly from the engine.

The engine from which our drawing was taken was made for the Sun Fire Insurance Company, in London, and from some experiments made by their agent, Mr. Samuel Hubert, appears to answer every purpose.

Fire-*engine* is also a name frequently given to a machine for raising water by steam, more properly called *steam-engine*, which see.

Fire-*escape*, a machine for escaping from windows when houses are on fire. Various machines of this kind have been invented by different persons; the following seems to be well adapted to the purpose for which it was designed. It was originally invented by the late John Daniel Maseres, esq.; and B. M. Forster, esq. has communicated to the public a description of it, with some improvements by himself, in the Philosophical Magazine. The principal parts of this machine, which is called the "fling fire-escape," are as follows: 1. The suspension iron A, (*Plate* XII. *Miscellany*, *fig.* 12.), which is formed like a ram-head commonly used for flinging goods from warehouses, with this difference, the bottom hooks are turned up close to the upright part, to form two close rings or eyes; the length of this iron is about four inches and a half, thickness of the iron out of which it is hammered is about half an inch.

2. The rope B. This is made of flax, and platted in a peculiar manner, for which there was a patent taken out. It is sold by Armstrong, St. John's-square, Clerkenwell, and measures about three-eighths of an inch in diameter. The rope must be in length somewhat more than twice the height of the window from the ground.

3. The regulator C. This is an oblong piece of beech wood, six inches and a half in length, three inches and a quarter broad, and about seven-eighths of an inch thick; in this there are four holes pierced for the rope to pass through; one of these is open at the side; there is also a notch at the top of this piece of wood, and an oblong hole about seven-eighths of an inch from the bottom.

4. The upper belt D is a stout leathern strap, about four feet three inches long, and one and a half broad, with a buckle to it.

5. The lower belt E is a strap of the same sort as the other; but the end, after being put through the buckle, is sewed down: this is for the purpose of security, in case the tongue of the buckle should by accident break.

6. The union strap F, so called from its connecting the regulator to the other parts of the machine. This is leathern, and is about a foot and a half long, and an inch and a quarter broad; it has, like the others, a buckle to it. It is stained black, which distinguishes it from the other leathern straps.

The method of putting together all these parts of the machine is, first to pass one end of the rope through the holes in the regulator, then through the two lower rings of the suspension iron; the upper belt is then to be passed through a doubling of the union strap; after which the rope is to be tied to that belt, and the knot secured by a string from slipping (which string is to pass through two small holes in the leather); and at about a foot below the rope is to be tied to the lower belt in like manner. Next, the union strap is to be put through the oblong hole in the regulator, and buckled; by which the upper belt and the regulator will be connected. The other end of the rope may be kept wound on a wooden roller, to prevent it from getting entangled.

Persons who purchase these machines should have a very strong iron hook, with a spring-catch, fixed to some secure part of the window-frame, or elsewhere; on this hook the suspension iron is to be hung by the upper ring, when any one wishes to descend from the window. The next operation is to step into the lower belt with both feet, and draw it up sufficiently high, so as to form a kind of swing to sit the part of the strap which is through the buckle is to be laid hold of with the left hand; and the buckle, with the right hand, is to be slipt to its proper place, according to the size of the person; the tongue is then to be put into one of the holes, as in buckling common straps. After this is done, the upper belt is to be somewhat loosely buckled round the chest, and then the rope which is on the roller is to be thrown out of the window on the ground.

Now all being ready for defcending, the perfon is to get out of the window, grafping tight with one or with both hands, the rope at fome convenient part, taking efpecial care not to meddle with the fufpenfion iron until quite out of the window; after which the rope below the regulator is to be laid hold of with the right hand, and to be let to run through the holes as faft as there may be occafion; for which purpofe, if neceffary, it may be eafily flipped out of the open hole; it will then have the check of only three holes: if the motion is wanted to be retarded, the rope is to be put into the notch at the upper part of the regulator.

When one perfon has defcended, and there is a neceffity for a fecond immediately to follow, the union ftrap is to be unbuckled; when the regulator will be feparated from the upper belt: the belts may then be very eafily drawn up, having the friction of the fufpenfion iron only, and the perfon above is to put on the belts as the other did, and is to be let down gradually, partly by the one below, and partly by managing the rope as the firft did: in this cafe great care muft be taken, as the check occafioned by the regulator is gone

Obfervations and Cautions.

It is not eafy to lay down exact rules for what number of holes the rope muft pafs through, as this muft vary according to the weight of the perfon, and other circumftan[illegible] It would be well, before the perfon gets out of the wind[illegible] to examine, firft, (abfolutely neceffary,) whether the fufpenfion iron is on the hook; then, that the three buckles are faft, the two knots tied, and that the rope is in the hole of the regulator which has the opening. Great care muft be taken that there is not any impediment to the free running of the rope; for which the wall of the houfe muft be examined, and any nails or hooks which may chance to be there removed; alfo iron fcrapers, and every thing wherein the rope may be likely to hitch.

Mr. B. M. Forfter has, in fome refpects, fimplified Mr. Maferes's machine, particularly in fubftituting the ram-head fufpenfion iron in the place of a more complicated, and, in his opinion, lefs fecure piece of mechanifm. (See *fig.* 13.) It confifts of a folid metal (in the latter improved ones) grooved cylinder, round which the rope coiled two or three times, by which a confiderable degree of friction was produced, and the rapid defcent prevented, which would otherwife happen. The metal cylinder is fupported on an iron frame, and fufpended by a ring, which ring is moveable in the focket. A is the moveable ring in the upper part of the frame; B is the frame, enclofing a grooved cylinder; and C is a metal bar to hold the cheeks together.

Fire, *Everlafting*, in *Pagan Theology*, is a kind of reputed facred fire worfhipped by the Gavers or Gabres in Perfia. Dr. Mounfey, formerly phyfician to the czarina's army, has given the following account of it: this perpetual fire rifes out of the ground in the peninfula of Abfcheron, about twenty miles from Baku, and three miles from the Cafpian fhore. The ground is rocky, over which is a fhallow covering of earth. If a little of the furface be fcraped off, and fire be applied to the hollow, it catches flame immediately, and burns without intermiffion, and almoft without confumption; nor is it ever extinguifhed unlefs fome cold earth be thrown over it, by which it is eafily put out. There is a fpot of ground, about two Englifh miles in extent, which has this property, where the earth continually burns; but the moft remarkable part of it is a hole about four feet deep, and fourteen in diameter. This fire is worfhipped, and is faid to have burnt many thoufand years. The cracks in the walls of the caravanfera, inhabited by the religious, are covered with flame, if a candle be held to them; and when there is occafion for a fmall light, no more is neceffary than to ftick one end of a piece of reed in the ground, and apply a lighted candle to the other; a flame will kindle at the top of the reed, and burn till it is extinguifhed by covering it. They burn ftones into lime, by filling a hole in the ground with a heap of them, and bringing a lighted candle to the hole, upon which the fire kindles, and in about three days burns the ftones fufficiently. The flame yielded by this fire, has neither fmoke nor fmell. This facred and adored phenomenon is nothing more than an inflammable vapour, which iffues in great quantity out of the ground in this place, and is fupplied by the naphtha with which the adjacent country abounds. Phil. Tranf. vol. xlv. for 1748, p. 296.

Fire, *Extinguifhing of.* The world has long been of opinion, that a more ready way than that in general ufe, might be found for extinguifhing fires in buildings, and it has generally been attempted upon the doctrine of explofion. Zachary Greyl was the firft perfon who put this plan into execution with any tolerable degree of fuccefs. He contrived certain engines, eafily manageable, which he proved before fome perfons of the firft rank to be of fufficient efficacy, and offered to difcover the fecret by which they were contrived, for a large premium given either from the crown, or raifed by a fubfcription of private perfons. But this fcheme meeting with no better fuccefs than things of this nature ufually do, he died without making this difcovery. Two years after this the people who had his papers found the method; and it was fhewn before the king of Poland and a great concourfe of nobility at Drefden, and the fecret purchafed at a very confiderable price. After this the fame perfon carried the invention to Paris and many other places, and practifed it every where with fuccefs. The fecret was this: a wooden veffel was provided holding a very confiderable quantity of water; in the centre of this there was fixed a cafe made of iron plates, and filled with gun-powder; from this veffel, to the head of the larger veffel containing the water, there proceeded a tube or pipe, which might convey the fire very readily through the water to the gun-powder contained in the inner veffel. This tube was filled with a preparation eafily taking fire, and quickly burning away; and the manner of ufing the engine was to convey it into the room or building where the fire was, with the powder in the tube lighted. The confequence of this was, that the powder in the inner cafe foon took fire, and, with a great explofion, burft the veffel to pieces, and difperfed the water every way: thus was the fire put out in an inftant, though the room was flaming before in all parts at once. The advantage of this invention was, that at fmall expence, and with the help of a few people, a fire in its beginning might be extinguifhed; but the thing was not fo general as it was at firft expected that it would prove; for though of certain efficacy in a chamber or clofe building where a fire had but newly begun; yet when the mifchief had increafed fo far, that the houfe was fallen in, or the top open, the machine had no effect. This was the contrivance firft difcovered by Greyl, and from which our chemift Godfrey took the hint of the machine, which he called the water-bomb, and would fain have brought into ufe in England. Act. Eruditor. ann. 1721. p. 183. (See Water-*Bomb.*) Dr. Hales propofed to check the progrefs of fire by covering the floors of the adjoining houfes with earth. The propofal is founded on an experiment which he made with a fir board, half an inch thick, part of which he covered with an inch depth of

damp garden mould, and then lighted a fire on the furface of the mould; though the fire was kept up by blowing, it was two hours before the board was burnt through, and the earth prevented it from flaming. The thicker the earth is laid on the floors, the better; however, Dr. Hales apprehends, that the depth of an inch will generally be fufficient; and he recommends to lay a deeper covering on the ftairs, becaufe the fire commonly afcends by them with the greateft velocity. Phil. Tranf. vol. xlv. for 1748, p. 277.

Mr. Hartley made feveral trials in the years 1775 and 1776, in order to evince the efficacy of a method which he had invented for reftraining the fpread of fire in buildings. For this purpofe thin iron plates are well nailed to the tops of the joifts, &c. the edges of the fides and ends being lapped over, folded together, and hammered clofe. Partitions, ftairs, and floors, may be defended in the fame manner; and plates applied to one fide have been found fufficient. The plates are fo thin as not to prevent the floor from being nailed in the joifts in the fame manner as if this preventative were not ufed: they are kept from ruft by being painted or varnifhed with oil and turpentine. The expence of this addition, when extended through a whole building, is eftimated at about five *per cent.* Mr. Hartley had a patent for this invention, and parliament voted a fum of money towards defraying the expence of his numerous experiments. (14 Geo. III. cap. 85.) The fame prefervative may alfo be applied to fhips, furniture, &c.

Lord Mahon (now earl Stanhope) has alfo difcovered and publifhed a very fimple and effectual method of fecuring every kind of building againft all danger of fire. This method he has divided into three parts, *viz.* under-flooring, extra-lathing, and inter-fecuring. The method of under-flooring is either fingle or double: in fingle under-flooring, a common ftrong lath of oak or fir, about one-fourth of an inch thick, fhould be nailed againft each fide of every joift, and of every main timber, fupporting the floor which is to be fecured. Other fimilar laths are then to be nailed along the whole length of the joifts, with their ends butting againft each other. The top of each of thefe laths or fillets ought to be at $1\frac{1}{2}$ inch below the top of the joifts or timbers againft which they are nailed; and they will thus form a fort of fmall ledge on each fide of all the joifts. Thefe fillets are to be well bedded in a rough plafter hereafter mentioned, when they are nailed on, fo that there may be no interval between them and the joifts; and the fame plafter ought to be fpread with a trowel upon the tops of all the fillets, and along the fides of that part of the joifts which is between the top of the fillets and the upper edge of the joifts. In order to fill up the intervals between the joifts that fupport the floor, fhort pieces of common laths, whofe length is equal to the width of thefe intervals, fhould be laid in the contrary direction to the joifts, and clofe together in a row, fo as to touch one another: their ends muft reft upon the fillets, and they ought to be well bedded in the rough plafter, but are not to be faftened with nails. They muft then be covered with one thick coat of the rough plafter, which is be fpread over them to the level of the tops of the joifts; and in a day or two this plafter fhould be trowelled over, clofe to the fides of the joifts, without covering the tops of the joifts with it.

In the method of double flooring, the fillets and fhort pieces of laths are applied in the manner already defcribed; but the coat of rough plafter ought to be little more than half as thick as that in the former method. Whilft this rough plafter is laid on, fome more of the fhort pieces of laths above-mentioned muft be laid in the intervals between the joifts upon the firft coat, and be dipped deep in it. They fhould be laid as clofe as poffible to each other, and in the fame direction with the firft layer of fhort laths. Over this fecond layer of fhort laths there muft be fpread another coat of rough plafter, which fhould be trowelled level with the tops of the joifts, without rifing above them. The rough plafter may be made of coarfe lime and hair; or, inftead of hair, hay chopped to about three inches in length may be fubftituted with advantage. One meafure of common rough fand, two meafures of flacked lime, and three meafures of chopped hay, will form in general a very good proportion, when fufficiently beat up together in the manner of common mortar. The hay fhould be put in after the two other ingredients are well beat up together with water. This plafter fhould be made ftiff; and when the flooring boards are required to be laid down very foon, a fourth or fifth part of quick-lime in powder, formed by dropping a fmall quantity of water on the lime-ftone a little while before it is ufed, and well mixed with this rough plafter, will caufe it to dry very faft. If any cracks appear in the rough plafter-work, near the joifts, when it is thoroughly dry, they ought to be clofed by wafhing them over with a brufh wet with mortar wafh: this wafh may be prepared by putting two meafures of quick lime, and one of common fand, in a pail, and ftirring the mixture with water till the water becomes of the confiftence of a thin jelly.

Before the flooring boards are laid, a fmall quantity of very dry common fand fhould be ftrewed over the plafter-work, and ftruck fmooth with an hollow rule, moved in the direction of the joifts, fo that it may lie rounding between each pair of joifts. The plafter-work and fand fhould be perfectly dry before the boards are laid, for fear of the dry rot. The method of under-flooring may be fuccefsfully applied to a wooden ftair-cafe; but no fand is to be laid upon the rough plafter-work. The method of extra-lathing may be applied to cieling joifts, to floping roofs, and to wooden partitions.

The third method, which is that of inter-fecuring, is very fimilar to that of under-flooring; but no fand is afterwards to be laid upon it. Inter-fecuring is applicable to the fame parts of a building as the method of extra-lathing, but it is feldom neceffary.

Lord Mahon has made feveral experiments in order to demonftrate the efficacy of thefe methods. In moft houfes, it is only neceffary to fecure the floors; and the extra-expence of under-flooring, including all materials, is only about nine pence per fquare yard; and with the ufe of quick-lime a little more. The extra-expence of the method of extra-lathing is no more than fix pence per fquare yard, for the timber, fide-walls, and partitions; but for the ceiling, about nine pence per fquare yard. But in moft houfes, no extra-lathing is neceffary. Phil. Tranf. vol. lxviii. for 1778, part ii. art. 4., p. 884, &c.

Flame

FLAME, (*flamma*, Latin,) is the actual burning, attended with heat and light, of a volatile combustible substance; and this substance may be either a comminuted solid, (*viz.* a powder,) or a vapour, or a gas.

The powder of rosin, and of other brittle resinous bodies, the farina of several plants, and some other powdered combustibles, when projected through the flame of a candle, or of a piece of burning paper, instantly take fire, and the flame spreads through the whole powdery cloud. Powders of this sort are used at the play-houses for representing a flash of lightning or other sudden light. Powdered rosin, and the powder of lycopodium, have been found to produce this effect equally well; yet the latter, when it may be procured, is by far preferable to the former, and that on account of its being an unadhesive light powder, easily brushed off from any thing, whereas the powdered rosin sticks to, and soils every thing that it happens to fall upon.

The vapour of certain inflammable fluids, such as spirit of wine, ether, spirit of turpentine, &c. are instantly inflamed by the contact of a candle, or other flaming body, or by a spark of electricity, and continue to burn as long as there is a sufficient supply of it.

The inflammable gases, when they are extricated either by the action of heat, or otherwise, from substances that contain them, may also be inflamed, and will burn in a similar manner. Thus, if iron filings and diluted sulphuric acid be placed in a bottle, an effervescence takes place, together with a copious production of hydrogen gas, which comes out in a stream from the aperture of the bottle, and it may be inflamed either by a lighted candle, paper, wood, &c. or by passing an electric spark through it. Thus also, when coals are lighted in a common fire, the heat softens their bituminous parts, and expels the inflammable gases, which burn and constitute the flame, as every body must daily experience. But besides the inflammable gases, heat expels from coals an aqueous vapour, a thick fluid like tar, and some gases that are not of a combustible nature, and those products are neither equal nor constant, that is, sometimes some of them predominate, and sometimes the other. The consequence of which is, that the flame of coals is continually wavering both in shape and intensity of colour. It frequently shifts from one place to another, and what gave a beautiful white light a few seconds before, has become a stream of dense and dark smoke. It may be hardly worth observing that the changeable inclination of the flame is owing to the motion of the air, which runs towards the fire in various directions.

The like thing takes place in the combustion of wood, and vegetable matter in general. The heat extricates the volatile and inflammable materials which take fire, and produce the flame.

In the combustion of charcoal, and of coak, (*viz.* charred mineral coal,) the flame and the smoke are very trifling, because the operation of charring has previously expelled from those materials a great portion of their volatile ingredients.

With respect to the process of the combustion, the same requisites are necessary with the combustion of volatile substances, which produce the flame, as with the combustion of solids; *viz.* the combustible must be heated to a certain degree, a fire must be communicated, and the combustion can only take place in contact with oxygen gas, or with substances which contain oxygen. See Combustion.

Thus, we have given a general sketch of the nature of flame; but there are several remarkable particulars belonging to every part of the above-mentioned process, which are highly deserving of notice, and which, of course, we shall now endeavour to point out successively.

The purposes for which mankind employs fires, or combustion in general, are either for the use of the heat, or for the use of the light. The heat is subservient to the numerous and important purposes of cooking victuals, of warming apartments, and thus rendering inhabitable such climates, as otherwise the human species could not live in; of giving existence to all metallurgic operations, to the making of glass, of lime for building, &c. &c. The light is subservient to purposes equally important. In short, it enables human beings to follow their operations, during the absence of the day-light nearly, if not full as well, as in the day-time. The flame of a single candle animates a family; every one follows his occupations, and no dread is felt of the darkness of night. Were it not for artificial light, how great a portion of the advantages of industry, and of real comfort, would the human species be deprived of.

When heat is wanted, then rough solid combustibles are used which give it in abundance, and at a cheap rate; but when light is wanted, then the purest and the most uniform combustibles must be used, otherwise an inadequate effect is produced, and a considerable quantity of materials is expended. In some uncivilized countries, slender faggots of some kind of resinous wood are used by way of candles. When lighted at one end they burn gradually, and afford a good deal of light, but it is unsteady, and encumbered with a good deal of smoke. Besides, these faggots are readily burnt out, and must be quickly replaced by new ones.

At present, in all civilized countries, the principal com-

buftibles that are ufed for the production of a bright and luminous flame, are wax, the fat of animals, under the general name of tallow, oil, either of fifh or of vegetables, and the inflammable gas of coals, which has but lately been introduced, at leaft in this country. The extenfive confumption of thefe materials, and the fucceffive increafe of their price, has obliged the induftrious to devife the beft means of producing the greateft effect with the leaft poffible quantity of materials.

Wax, tallow, and oils muft be rendered volatile before they will produce a flame, but for this purpofe it is fufficient to volatilize a fmall quantity of any of them, fucceffively; for this fmall quantity will fuffice to give a ufeful flame, and hence we muft admire the fimple, yet wonderful contrivance of a common candle or lamp. This contrivance contains a confiderable quantity of the combuftible fubftance, fufficient to laft feveral hours; it has likewife, in a particular place, a flender piece of fpongy vegetable fubftance, called the *wick*, which in fact is the fire place, or laboratory where the whole operation is conducted. The wick which, in the formation of the candle, or preparation of the lamp, has been partly or entirely foaked in the wax, or tallow, or oil, is fet fire to by the approach of fome other fubftance actually burning; this heat renders volatile and inflames that part of the wax, oil, &c. which is in the wick, and at the fame time foftens that which is next to it; the firft portion of the wax, &c. being thus confumed, the wick is, in confequence of its capillary attraction, enabled to imbibe more materials for the maintenance of the flame, and fo on in fucceffion until the whole is exhaufted.

There is a circumftance frequently attending the firft lighting of a candle, which demands a fhort explanation in this place. It is, that at firft the candle fometimes burns dimly, and looks as if it would go out. The method of reviving the flame in fuch cafes is to lift up the candle perpendicularly with a quick motion, three or four times fucceffively, which immediately revives the light. The reafon of the firft dimnefs is that the wax or tallow, by being too cold or too hard, is not melted by the combuftion of that fmall portion which is in the wick, and of courfe cannot fupply the wafte of the wick; but by the lifting up of the candle, the air beats down the flame upon the wax or tallow adjoining to the wick, which melts it, and enables it to run up into the pores of the wick, where it is rendered volatile, and is inflamed, &c.

That part of the combuftible which is fucceffively rendered volatile by the heat of the flame is not all burnt, but part of it efcapes in the form of fmoke through the middle of the flame, becaufe that part cannot come in contact with the oxygen of the furrounding atmofphere; hence it follows, that with a large wick and a large flame, this wafte of combuftible matter is proportionately much greater than with a fmall wick and a fmall flame. In fact, when the wick is not greater than a fingle thread of cotton, the flame, though very fmall, is, however, peculiarly bright, and free from fmoke; whereas in lamps with a very large wick, fuch as are often fufpended before butcher's fhops, or with thofe of the lamp lighters, the fmoke is very offenfive, and in great meafure eclipfes the light of the flame.

In order to avoid this inconvenience, the ingenious Mr. Argand made that famous contrivance of a lamp, which now juftly goes by his name. He made the burner or wick thin and circular, with a free paffage for the air through the middle. In this conftruction a very thin and circular flame comes in contact with a vaft quantity of air both within and without the circle, in confequence of which none of the volatilized oil efcapes without burning, and the flame is very brilliant and active. This fhews the reafon of what is commonly faid of this lamp, namely, that it confumes its own fmoke. With refpect to the original conftruction, and the fucceffive improvements of this admirable lamp, we muft refer the reader to the article LAMP.

Inftead of a circular form, the wick has alfo been made thin and oblong; but though this conftruction has fome advantage over the common lamp, yet it is far inferior to Argand's. A circular or an oblong wick has likewife been tried in wax or tallow candles, but the attempts have not been attended with any remarkable advantage.

Another confequence of the want of oxygen in the middle of the large flame of a lamp or candle, is the formation of a coaly concretion at the extremity of the wick. This arifes from the coaly or groffer particles of the combuftible which are too heavy to become volatile, and at the fame time do not come in contact with the oxygen which is neceffary for their combuftion; hence they accumulate and fpread out fomewhat like a fungus. If the wick be inclined a little, fo that the end of it may juft project out of the flame, which always goes ftraight upwards; then no coaly concretion is formed. In the lamps which illuminate the ftreets of London, the wick lies nearly horizontal, in confequence of which they feldom contract any coaly concretion.

Of the three principal materials for producing a ufeful bright flame, *viz.* wax, tallow, and oil, the firft and fecond are moftly ufed within doors in this country; but the fifh oil, the combuftion of which is attended with an unpleafant fmell, is moftly ufed for ftreet lamps and other out of doors purpofes; excepting indeed when Argand's lamps are ufed, for in thefe the oil gives no bad fmell. Oil of olives burns without any offenfive fmell; therefore much ufe is made of it for lamps in private houfes in thofe countries where it may be had at a cheap rate, as in Italy, the fouth of France, &c.

Befides the above, a new material has of late been attempted to be introduced in this country, for the purpofe of lighting houfes, ftreets, manufactories, &c. the material is the inflammable gas of coals. Every body muft know, that when coals are burning in a common fire place, a flame more or lefs luminous (according as it is more or lefs encumbered with incombuftible fmoke and vapour) iffues from them; and they frequently emit fome very beautiful ftreams of a flame remarkably bright. All this, as we have already mentioned, arifes from the gafes which are extricated from the coals by the heat. It was natural to imagine that fuch gas might be received in proper refervoirs, and might afterwards be forced out of fmall apertures, which being lighted might ferve, as the flames of candles, to illuminate a room or other place. The trial was eafily made, and it was attended with the defired effect. The principle of the apparatus and of the operation is as follows: The coal is placed in large iron veffels, called retorts, to the apertures of which iron pipes are adapted, which terminate in a veffel, or veffels, called gafometers, or refervoirs, which are inverted in water. The retorts thus charged are placed upon the fire, the action of which extricates the gas from the coals that are within the retorts, together with an aqueous vapour, a thickifh fluid, or tar, &c. Thefe products are conveyed through the above-mentioned pipes under the gafometers where the gas is wafhed, and remains ready for ufe. There are then other fmaller pipes from the gafometer, which branch out into fmaller ramifications, until they terminate into the places where the lights are wanted. The extremities of the pipes have fmall apertures, out of which the gas iffues, and the ftreams being lighted at thofe apertures, will burn with a clear and conftant flame as long as the fupply of gas continues. All the pipes which come from the

gasometer are furnished with stop-cocks, in order both to prevent the useless waste of gas, and to regulate the sizes of the flames.

The method of producing the gas being thus contrived, the next step was to determine how far such lights might be employed, consistently with expence, safety, &c. A few shops in London were lighted with it, but the use was soon discontinued, as it was said, principally on account of the unpleasant smell. A proposal, and some attempts were made for lighting some of the streets of London by means of this coal gas; but either the mysterious nature of the proposals, or the expence attending the operation, or some other cause of obstruction, has not as yet allowed the adoption of the plan. Other attempts of the like nature have been made elsewhere, but of their successes we have no authentic account; excepting however of one, which was laid before the Royal Society by the operator, Mr. Murdock, and is published in the Philosophical Transactions for the year 1808. The precision with which the particulars are stated in Mr. Murdock's account, and the essential use of which such statements may be to a vast number of persons, who are now engaged in similar examinations in this new branch of civil economy, induce us to transcribe the most essential part of the account in the present article; reserving to add what future improvements may come to our notice to the article GAS *Lights*.

"These facts and results, Mr. Murdock says, were made, during the present winter, at the cotton manufactory of Messrs. Philips and Lee, at Manchester, where the light obtained by the combustion of the gas from coal is used upon a very large scale; the apparatus for its production and application having been prepared by me at the works of Messrs. Boulton, Watt, and Co. at Soho.

"The whole of the rooms of this cotton mill, which is, I believe, the most extensive in the united kingdom, as well as its counting-houses and store-rooms, and the adjacent dwelling house of Mr. Lee, are lighted with the gas from coal. The total quantity of light used during the hours of burning has been ascertained, by a comparison of shadows, to be about equal to the light which 2500 mould candles, of six in the pound, would give; each of the candles with which the comparison was made consuming at the rate of 4-10ths of an ounce (175 grains) of tallow per hour.

"The burners are of two kinds: the one is upon the principle of the Argand lamp, and resembles it in appearance; the other is a small curved tube with a conical end, having three circular apertures or perforations, of about a thirtieth of an inch in diameter, one at the point of the cone, and two lateral ones, through which the gas issues, forming three divergent jets of flame, somewhat like a fleur-de-lis. The shape and general appearance of this tube has procured it, among the workmen, the name of the cockspur burner.

"The number of burners employed in all the buildings amounts to 271 Argands, and 633 cockspurs; each of the former giving a light equal to that of four candles of the description above-mentioned; and each of the latter a light equal to two and a quarter of the same candles; making therefore the total of the gas light a little more than equal to that of 2500 candles. When thus regulated, the whole of the above burners require an hourly supply of 1250 cubic feet of the gas produced from cannel coal; the superior quality and quantity of the gas produced from that material having given it a decided preference in this situation over every other coal, notwithstanding its higher price.

"The time during which the gas light is used may, upon an average of the whole year, be stated at least at two hours per day of 24 hours. In some mills, where there is over work, it will be three hours; and in the few where night work is still continued nearly twelve hours. But taking two hours per day as the common average throughout the year, the consumption in Messrs. Philips' and Lee's mill will be $1250 \times 2 = 2500$ cubic feet of gas per day; to produce which 700 weight of cannel coal is required in the retort. The price of the best Wigan cannel (the sort used) is $13\frac{1}{2}$*d.* per cwt. (22*s.* 6*d.* per ton) delivered at the mill, or say about eight shillings for the seven hundred weight. Multiplying by the number of working days in the year (313), the annual consumption of cannel will be 110 tons, and its cost 125*l.*

"About one-third of the above quantity, or say forty tons of good common coal, value ten shillings per ton, is required for fuel to heat the retorts, the annual amount of which is 20*l.*

"The 110 tons of cannel coal, when distilled, produce about 70 tons of good coak, which is sold upon the spot at 1*s.* 4*d.* per cwt. and will therefore amount annually to the sum of 93*l.*

"The quantity of tar produced from each ton of cannel coal is from 11 to 12 ale gallons, making a total annual produce of about 1250 ale gallons, which not having been yet sold, I cannot determine its value.

"The interest of the capital expended in the necessary apparatus and buildings, together with what is considered as an ample allowance for wear and tear, is stated by Mr. Lee at about 550*l.* per annum, in which some allowance is made for this apparatus being made upon a scale adequate to the supply of a still greater quantity of light, than he has occasion to make use of.

"He is of opinion that the cost of attendance upon candles would be as much, if not more, than upon the gas apparatus; so that, in forming the comparison, nothing need be stated upon that score, on either side.

"The economical statement for one year, then, stands thus:

Cost of 110 tons of cannel coal - -	£ 125
Ditto of 40 tons of common ditto -	20
	145
Deduct the value of 70 tons of coak -	93
The annual expenditure in coal, after deducting the value of the coak, and without allowing any thing for the tar, is therefore - -	52
And the interest of capital, and wear and tear of apparatus - - -	550
Making the total expence of the gas apparatus per annum, about - - -	600

"That of candles, to give the same light, would be about 2000*l.* For each candle, consuming at the rate of 4-10ths of an ounce of tallow per hour, the 2500 candles burning, upon an average of the year, two hours per day, would, at one shilling per pound, the present price, amount to nearly the sum of money above-mentioned.

"If the comparison were made upon an average of three hours per day, the advantage would be still more in favour of the gas light.

"At first, some inconvenience was experienced from the smell of the unconsumed, or imperfectly purified gas, which may in a great measure be attributed to the introduction of successive improvements in the construction of the apparatus, as the work proceeded. But since its completion, and since the persons to whose care it is confided have be-

come familiar with its management, this inconvenience has been obviated, not only in the mill, but alſo in Mr. Lee's houſe, which is moſt brilliantly illuminated with it, to the excluſion of every other ſpecies of artificial light.

"The peculiar ſoftneſs and clearneſs of this light, with its almoſt unvarying intenſity, have brought it into great favour with the work-people. And its being free from the inconvenience and danger reſulting from the ſparks and frequent ſnuffing of candles, is a circumſtance of material importance, as tending to diminiſh the hazard of fire, to which cotton mills are known to be much expoſed."

In the burning of candles or oil lamps, the heat of the flame ſoftens and attenuates the materials, and converts them partly into an elaſtic fluid which takes fire ſucceſſively and maintains the flame. In the burning of coals, wood, turf, &c. various gaſes, as well as vapours, are extricated from them, but theſe products are not all combuſtible; therefore thoſe which are not combuſtible tend to check the activity of the flame which ariſes from the combuſtion of the others. The gaſes which are principally extricated from the above-mentioned materials are hydrogen gas, azotic gas, and carbonic acid gas; the firſt of which only is highly inflammable in all its combinations; and it is hardly ever yielded pure by any of the above-mentioned materials. Its uſual combinations are either with ſulphur, or with carbon, or with phoſphorus; hence it derives the denominations of ſulphurated, carburated, or phoſphorated, hydrogen gas.

The flames of different combuſtibles are not all attended with an equal production of heat and light. Sulphur burns with a weak flame; phoſphorus with a very denſe one. Spirit of wine burns with a very ſlight flame in point of light, but a very powerful one with reſpect to heat; ſo that if an Argand lamp be charged with oil, and another ſimilar lamp be charged with ſpirit of wine, the flame of the latter will not have a quarter of the light of the other, but it gives more than twice as much heat as the other. The flame of ſpirit of wine is not accompanied with any ſmoke. The flame of ether is denſer, but produces ſmoke. The flame of ſpirit of turpentine is attended with a very denſe ſmoke. The flame of pure hydrogen is very faint. This flame of hydrogen produces a remarkable phenomenon, which deſerves to be mentioned in this place.

If a phial, containing the materials proper for the production of hydrogen gas, (*viz.* iron filings and diluted ſulphuric acid,) be furniſhed with a tube having a ſmall aperture for the exit of a ſtream of the gas, and if this ſtream be lighted, a flame will continue to burn at that aperture as long as the materials continue to give out the gas. Now, if a glaſs tube of about an inch in diameter, and about a foot long, be held ſtraight up, with its aperture juſt over the above-mentioned flame, a ſound will be heard, ſomewhat like a delicate ſound of an organ pipe. This ſound varies according to the ſize of the tube. No very ſatisfactory explanation has, as yet, been given of this ſingular phenomenon.

The flames of volatile combuſtibles that are more compound in their nature, vary conſiderably with reſpect to the intenſities of their heat and light. A curious phenomenon takes place in uniting the flames of two candles, *viz.* the light is conſiderably increaſed. Let a perſon hold two candles before his face, at firſt ſeparate, and then with their flames joined. Upon the junction of the two flames, his face will appear much more illuminated than it was before. "It is conjectured," Dr. Prieſtley ſays, "that the union of the two flames produces a greater degree of heat, and that this cauſes a farther attenuation of the vapour, and a more copious emiſſion of the particles of which light conſiſts."

The effects which we have juſt been enumerating are ſuch as take place in common atmoſpheric air.

The various colours of the flames of ſimple and compound bodies are likewiſe highly deſerving the attention of philoſophers. Certain combuſtibles, even of the pureſt kind, burn with flames having peculiar tints; but much ſtronger colours may be communicated to their flames by the admixture of various ſubſtances, eſpecially of ſalts that are of an earthy or metallic nature.

The flame of a common candle is far from being of an uniform colour. The loweſt part of the flame is always blue; and when the flame is ſufficiently elongated, ſo as to be juſt ready to ſmoke, the tip is always red.

As for the colours of flames that ariſe from coals, wood, and other uſual combuſtibles, their variety, which hardly amounts to a few ſhades of red, or purple, intermixed with the bright white light, ſeems principally to ariſe from the greater or leſs admixture of aqueous vapour, denſe ſmoke, or, in ſhort, of other incombuſtible products.

Spirit of wine burns with a blueiſh flame. The flame of ſulphur has nearly the ſame tinge. The flame of zinc is of a bright white. The flame of moſt of the preparations of copper, or of the ſubſtances with which they are mixed, is greeniſh-blue. Spirit of wine, mixed with common ſalt, burns with a very unpleaſant effect, as may be experienced by looking at the ſpectators who are illuminated by ſuch light. If a ſpoonful of ſpirit of wine and a little boracic acid be ſtirred together in a cup, and then be inflamed, the flame will be beautifully green. If the ſpirit of wine be mixed with a little ſtrontian earth in powder, or with any of its ſaline preparations, it will afterwards, on being inflamed, burn with a red, or rather purple flame. If the ſpirit of wine be mixed with barytes, its flame will have a beautiful yellow appearance. Such are the principal means of colouring flames, the admixture of various other ſubſtances will alſo impart ſome ſhades of colour to flaming bodies, but not nearly ſo ſtrong as the above.

Some years ago an elegant and curious exhibition, under the title of "Philoſophical Fire-works," was ſhewn in London by an induſtrious foreigner, named Diller. The exhibition conſiſted of the flames of certain gaſes or vapours which iſſued out of a variety of ſmall apertures at the ends of ſhort tubes, which were diſpoſed in the forms of wheels, pyramids, ſpirals, tridents, &c. Out of theſe apertures the flames were gradually made to increaſe and decreaſe alternately; ſo that ſometimes the room looked as bright as if it were illuminated by the ſun, and at other times the flames would be barely diſcerned. But the moſt pleaſing effect aroſe from the colours of theſe flames, as there were beautiful greens, yellows, reds, purples, &c. Mr. Diller died, and it ſeems that he did not leave the ſecret of the preparations behind him; for no one has ſince been able to exhibit any thing equal to thoſe philoſophical fire-works. The ſmell of ether, which predominated in the exhibition room, ſeemed to ſhew that Mr. Diller made great uſe of that liquid.

The combuſtible vapours and gaſes are not all inflamed with equal readineſs. Hydrogen gas may be inflamed not only by the contact of another flaming body, but even by a very ſmall electric ſpark. An electric ſpark a little more powerful will fire ſpirit of wine and ether, eſpecially when thoſe fluids are a little warm. Spirit of turpentine, and ſome eſſential oils may be inflamed, not only by the above-mentioned means, but even by the action of cold acids. Put about a ſpoonful of oil of turpentine in a cup, and pour over it about half that quantity of ſtrong nitrous acid previouſly mixed with a few drops of ſulphuric acid. The oil

of turpentine will immediately burſt out into a flame merely in conſequence of the action of the acid.

The thick fat oils muſt be heated to a conſiderable degree, and in that ſtate a flaming body muſt be brought in contact with their vapour, before they will be inflamed. Even when raiſed to a very high temperature, they ſeldom will of themſelves burſt out in a flame. If a veſſel containing oil be ſet upon a fire, a ſmoke or vapour begins to riſe from it, which grows by degrees denſer and denſer; and at laſt it begins to ſhine in ſome places near the ſurface of the oil, ſomewhat like an electric light; yet it does not flame; but if in this ſtate a flaming body, like a candle, a match, &c. be brought within the vapour, the latter will be inſtantly inflamed, breaking out with a ſort of exploſion, and will continue to burn until the oil is in great meaſure conſumed.

Beſides the uſe of their light, the flames of candles, and eſpecially of lamps, are often uſed for the ſake of the uniform heat which they give; and when no very great degree of heat is wanted, the uſe of ſuch flames muſt be allowed to be incomparably more commodious, and more economical than a common fire. The enameller, the mineralogiſt, and the philoſophical inſtrument makers, make great uſe of the heat of candles and lamps, the flames of which they frequently urge by means of the blow-pipe. An Argand lamp, eſpecially when charged with ſpirit of wine, (for which purpoſe, however, the lamp muſt be made in a particular manner,) inſtead of oil, forms a pretty powerful furnace for ſmall diſtillations, decoctions, &c. but even the flame of a ſingle common lamp is ſufficient for a great variety of delicate purpoſes.

The word flame, beſides its true meaning, which we have already explained, and which denotes the combuſtion of a volatile combuſtible body attended with the emiſſion of heat and light, has often been indiſcriminately applied to every kind of luminous appearance, provided its light had a pretty evident degree of intenſity. Thus all phoſphoreſcent bodies, electrical light, northern lights, &c. have been called flames by a variety of writers. Certain phenomena really have much the appearance of true flames; yet their real nature has not been ſufficiently inveſtigated. Thus the *ignis fatuus*, or *Jack-a-lanthorn*, is ſuppoſed to be nothing more than phoſphorated hydrogen, which being extricated from certain materials in particular places, comes out of the ground, and burns on the ſurface of it; for it is a property of that gas to take fire of itſelf the moment it comes in contact with reſpirable air. The nature of thoſe appearances in the ſky, which have been called flames, is moſtly unknown to us. See METEORS, and IGNIS *fatuus*.

By ſome authors, flame is defined to be *light emitted from fire*; by others, who have followed Newton, flame is ſaid to be a vapour heated red-hot; for Newton in his Optics ſays, "Is not flame a vapour, fume, or exhalation heated red-hot, that is, ſo hot as to ſhine? For bodies do not flame without emitting a copious fume, and this fume burns in the flame."

With reſpect to the firſt definition, we imagine that the preceding part of the preſent article has clearly ſhewn that not all the light which is emitted from a fire is flame; and ſuch for inſtance is the light emitted from a red-hot cinder, or of a coal nearly exhauſted of its gas. As for ſir I. Newton's query, it may be juſtly ſaid, that the ſtate of chemical knowledge at his time could not furniſh him with better ideas reſpecting the nature of flame.

Flint

Flint, *Silex cretaceus*, Linn. *Igniarius*, Carth. et Wall. *Pyromachus*, Wern. *Quartz-Agathe pyromaque*, Hauy. *Feuerſtein*, Germ. *Flinta*, *Böſs-flinta*, Swed. *Pierre à feu*, Fr.

The flint, one of the moſt remarkable of the ſiliceous ſtones, has frequently been confounded with other hard ſtones of the ſame claſs; the quality it poſſeſſes in an eminent degree of giving ſparks with the ſteel, and the popular denomination it has thence derived among almoſt all nations, have been the principal cauſes of this confuſion, which may eaſily be avoided by a proper attention to its more diſtinguiſhing characters. It muſt, however, be confeſſed, that, in ſome caſes, its diagnoſis is rendered uncertain by its too great affinity to *Hornſtone* and Flint *ſlate*, (ſee thoſe articles,) and by its gradual tranſition into theſe kindred ſtones.

Its colour is chiefly grey, of which yellowiſh, blueiſh, and ſmoke-grey, are the more uſual ſhades, and theſe paſs, the latter into greyiſh-black, the former into all the well known tints of yellow, red, and reddiſh-brown, that approach it, to the carnelian. It is ſometimes found perfectly black,

and also displaying several of the just-mentioned colours in stripes, zones, and spots.

Flint occurs massive, in angular pieces of various size, in globular boulders, frequently tapering at one end, (the *petrified melons of Mount Carmel*, vulgarly so called, belong to this variety): also in knobbed, branching, amorphous, perforated pieces, and as hollow balls filled with various substances. (See GEODE.) Besides these forms, it sometimes adopts those of crystals, which however do not belong to it, as some writers have supposed, but are supposititious: from calcareous spar it derives the double three-sided pyramid, as also the six-sided prism acuminated by three planes; and it has been likewise observed in crystals formed after those of lamellar barytes or caulk. It is also frequently observed, (contrary to what we know of horn-stone,) in extraneous external shapes, as petrifactions of species of echinus, madrepora, coral, &c. Surface little glistening, and of various degrees of smoothness, often coated by, and passing into, a white or yellowish-white crust, of which we shall say more hereafter. Fracture conchoidal, never perfectly splintery; internal surface but little glistening, or dull, of an almost imperceptibly fine grain. Fragment sometimes tabular, very sharp-edged, and more or less translucid in proportion to the lighter or deeper colours of the stone. It is easily frangible. Its hardness appears to be in a ratio with the depth of its colours: in general it will scratch quartz.

Specific gravity, according to Gellert, 2.581; Blumenbach 2.594; Gmelin 2.999. To these physical characters of flint we may add the one afforded by its phosphorescence, and the peculiar smell, which are manifested when two pieces are rubbed together.

Flint is infusible before the blow-pipe without addition, but loses its colour and becomes opaque. By the intense heat excited by a stream of oxygen gas, Mr. Ehrmann found it to melt into a white glistening quartz-like globule. Its constituent parts are,

	Klaproth.	Vauquelin.	Wiegleb
Silica - -	98.00	97.0	80
Lime - -	0.50	0	2
Alumine -	0.25 }	1	18
Oxyd of iron -	0.25 }		
Loss - -	1.00	2	0
	100	100	100

Flint is met with in most parts of Europe, particularly in the north of France, in England, Saxony, Tyrol, Podolia, &c. Norway seems to be destitute of flint, as it is of chalk; also in Sweden it is scarce. In Denmark it is principally at Wordenborg and Taxoë, in the island of Seeland, that some chalk-hills with imbedded flints are found; and more copiously in the remarkable Steevens-Klint. It occurs but seldom in primitive mountains, and when found there, only in veins, as, for instance, in the Saxon Erzgebirge. Its principal geognostic situation is in fletz-mountains, where it occurs chiefly in common compact lime-stone or in chalk; in the sand-stone formation, where it is also met with in the shape of those conglomerates vulgarly called *Pudding-stone*. See this article.

Though the formation of flints is a subject which has engaged the attention of many naturalists, yet but few opinions have been broached respecting it that will at all stand the test of closer investigation. The theory which explains their origin by a metamorphosis of one earth into another, though it may appear absurd to the chemist who is unable to produce the same changes in his laboratory, has notwithstanding had its able and celebrated defenders. Some have endeavoured to prove that the argillaceous, others, that the calcareous earth, underwent this conversion into flint. Buffon was an advocate for the argillaceous origin of this stone; and the observations of Pallas appeared to corroborate the opinion of the French naturalist; for he found that the *Ephemera horaria*, which abounds in the Moskua, had in some places perforated the clayey bottom of this river with innumerable tubes closely joined; and in the adjacent fields pieces of perfect flint frequently occurred that were pierced precisely in the same manner as the clay, from which they were not found to differ in any respect but in fracture and hardness. In the same manner he states that, in the small river Sunghir, near Woldemir, black, globular, rolled masses occur, which, on being broken, exhibit, from their circumference to the central part, a gradual transition from real clay and clay-stone into what he considers as perfect flint. With all deference, however, to the great merits of this excellent observer, we cannot but see in his account one of those frequent cases in which hard stones of the siliceous class (and clay stone and jasper belong to it) have been mistaken for real flint merely by reason of their giving copious sparks with steel: for this appears to be the character on which Pallas has chiefly founded his diagnosis of the stone he describes.

According to other geologists, it is lime-stone, and principally chalk, which have undergone a transformation into flint: an opinion which Wallerius endeavoured to support both by geognostical and chemical facts, and which was followed by Linnæus himself. Also Gillet-Laumont and Girod-Chantrans, from observations they respectively made in various parts of France, were induced to consider flint as a mere modification of chalk. The principal ground on which this hypothesis appears to rest is the geognostic relationship that subsists between the strata of chalk and of flints, together with the intimate union of the boulders of flint and their white earthy crust; both these substances being so completely incorporated with one another, as to preclude the possibility of our ascertaining the line where each may be considered as perfectly distinct from the other. This latter reason, though specious, may, however, lose much of its force by future analysis of that white earthy substance. To us it appears that most of the boulders of flint, such as they are found embedded in chalk, are but seldom furnished with a coating throughout calcareous: it seems to be composed of a twofold crust, *viz.* an outer chalky one, originating from the matrix of the stone; and an inner one passing over into the outer, and, by reason of the similarity of colour, not distinguishable by the eye. This inner crust shews no effervescence with acids; it appears to be siliceous, and may perhaps be properly looked upon as the result of incipient decomposition; especially if it be considered that flints with uncoated surface, by a long exposure to the influence of moisture and other atmospheric agents, have been known to acquire another thin coating, (but not calcareous,) with loss of weight.

Many geologists of the present day, who consider the idea of a transmutation of the calcareous into siliceous earth as unworthy the advanced state of modern chemistry, at the same time that they are unwilling to have recourse to floods and other revolutionary agents for rolling fragments of flint into boulders, and disposing them in the regular manner in which they are now found, have adopted, some, the hypothesis of infiltration by means of a siliceous fluid; others, that of a forcible injection of melted flint into vacuities previously existing in the calcareous strata. But either of these

theories is open to objection; and, indeed, the same objections appear to apply to both. It is difficult to account for the strange predilection the flinty fluid (whether its fluidity proceeded from water or fire) has manifested for fletz lime-stone, particularly for chalk; while other fletz and primitive rocks, several of which must be supposed to have been equally exposed to it, remained perfectly untouched. Nor is it much easier to conceive how that supposed fluid can have found its way into so many approximate, but perfectly distinct, hollows in the chalk, without more or less penetrating the intermediate parts, or leaving traces of masses that were connected with the nodules as they now appear; not to mention the improbability that so many almost contiguous vacuities (especially those that must be supposed to have been the moulds for the frequently occurring tabular expansions of flint) should not have yielded to the pressure of the superincumbent stratum. As, moreover, these hypotheses are silent respecting the origin of this flinty mass, (although a substance so different in its appearance from common silex), another theory of the generation of the nodules of flint has been proposed, which, however, is not likely to meet with any followers among those geologists, whose exalted ideas of the present state of chemical knowledge lead them to suppose that the result of their analytical and synthetical processes must of necessity, in all cases, square with those great operations that, with her ample means, and assisted by a long series of ages, have been accomplished by Nature in the vast laboratory of the earth. We allude to the hypothesis, according to which all flint, whether it be found in nodules or as flat tabular plates, originates from the flesh of a stratum of marine gelatinous animals, which perished by some revolution, and were buried in their shells. The internal aspect of the nodules, and their being almost constantly found imbedded in fletz lime-stone, which, by most geologists, is allowed to owe its existence to shells and other calcareous coverings of testaceous animals, seems first to have suggested this new idea; which, strange as it appears, may be allowed to have as much plausibility as any of the former; especially as it may be adapted equally well to the system of an igneous, and to that of an aquatic origin of terrestrial bodies. Mr. Patrin is of opinion, that when the chalk was deposited at the bottom of the sea, in those strata which we now see, it met, on other strata already existing, a vast number of marine bodies, shells, madrepores, &c. while others were carried along with the precipitating chalk itself, such as medusæ, &c. whose soft and gelatinous bodies, while they occupy much space, contain but little substance. When all these marine animals were buried in the chalk, and their decomposition took place, those of a consistence merely gelatinous left in their matrix an empty space, nearly equal to the space they occupied when alive: their substance, almost in a state of fluidity, was absorbed by the porous sides of the cavity; and by the combination of this animal fluid with the chalk, these sides were, by some unknown agent, converted into flint. In this manner Mr. Patrin accounts for the generation of nodules that are either hollow or filled up with chalk; which latter may have been deposed there by means of some aperture, or may have penetrated through the flinty coat itself, when still in a state of softness. As to those nodules, the central part of which is of a more perfectly flinty nature than that nearer the circumference, they were, according to the same author, formed of marine animals of more consistence or solidity; and it is in these particularly that vestiges of animal organization are found. The more consistent part of the body of these animals produced the more perfect flint, such as we see it in such solid nodules; while the fluid which escaped from the body, by the effects of decomposition, formed the external layers of this nucleus, which, being mixed with the substance of the chalk, became less perfect flint the farther it removed from the central part. According to this explication, the most imperfect part of a nodule of flint would be that, which, in its original situation, occupied the lowest place, and towards which the fluid which escaped from the more solid nucleus must naturally have taken its direction. This, however, is never found to be the case; nor has Mr. Patrin endeavoured to account for that circumstance. What appears to be much in favour of this explanation is, that the whole body of echini in their shells has been found converted into flint: and Gillet-Laumont has frequently observed that those echini, which he met with in the chalk strata of Montreuil-sur-Mer, were furnished with a flinty appendage issuing from their mouths, and which appears to have been the animal substance converted into a fluid state by decomposition. The same circumstance is not seldom observed in bivalve shells, whose gelatinous inhabitants have been found in a perfectly siliceous state; while the shells themselves had retained their original calcareous nature, and were partly converted into spar. In cases where the gelatinous marine bodies were in such abundance that no intermediate space was left for the deposition of chalk, the flint has been formed into large masses and plates of considerable extent. Dr. Darwin's ideas on this subject are nearly the same, and modified only by his adopti g a different theory for explaining the conversion of the gelatinous animals into flint. He conjectures that the nodules of flint found in chalk-beds have gained their form, as well as their dark colour, from the flesh of the shell-fish from which they had their origin, but which have been so completely fused by heat, or heat and water, as to obliterate all vestiges of the shell; in the same manner as (according to the doctor's opinion) the nodules of agate and onyx were produced from parts of vegetables, but which had been so completely fused as to obliterate all marks of their organization.

A remarkable circumstance, relating to the geological history of flint, should not be passed over unnoticed in this place: it is that sir Henry Englefield has observed in the neighbourhood of Carisbrook, and in other parts of the Isle of Wight, an immense number of nodules of flint, all of which, though not removed out of their places, and retaining perfectly their original shape, were more or less burst or shattered. Some few were only split into large pieces, but the greater part were broken into small fragments, and some absolutely reduced to impalpable powder. The chalk strata in which they were imbedded had an inclination of at least 67 degrees, and perpendicular fissures traversed the whole. Sir Harry conjectures, "that when the tremendous convulsion took place which sunk them to the situation in which they now appear, (at which time the channel which separates the Isle of Wight from the main land was perhaps formed,) the strata of chalk, in the act of subsidence, had a tendency to slide on each other; and this would be exerted most sensibly where, from the admixture of the flints, the cohesion of the parts of the chalk was the weakest. This motion, or rather strain of so enormous a weight, might in an instant shiver the flints, though their resistance stopped the incipient motion; for the flints, though crushed to powder, are not displaced, which must have been the case had the bed slipped sensibly." This theory appears to us very unsatisfactory, though we are not prepared to give a better. The advocates for the igneous origin of flint may,

perhaps, be inclined to account for the phenomenon by an accidental sudden cooling of the flinty masses.

We conclude this article by adding a few words on the *uses* to which flint is applied, some of which are of considerable importance. The one derived from its giving copious sparks with steel is the most ancient and generally known; but the art of cutting or rather breaking this stone into regularly shaped gun-flints is of more modern date, and was not practised till a considerable time after the invention of fire-arms. The mode of making gun-flints has for a long time been involved in fable and mystery: the most absurd and contradictory accounts having been given of it by various authors; and it was not till lately that we have been made fully acquainted (by Hacquet of Vienna, and by Dolomieu) with the simple manner in which these flints are manufactured in Gallicia and in France, where they constitute an important article of trade. (See GUN-FLINT.) The art of squaring and chipping flint was practised long before that of making gun-flints; and as this latter requires exactly the same management and the same tools, the former cannot properly be called a lost art, though, on account of the expensiveness of such square pieces of flint, if employed for constructing walls and covering roofs, it is not much practised. The north wall of the Bridewell at Norwich, mentioned in a letter of Mr. Baker, in the 43d volume of the Philosophical Transactions, was built of flints, "squared to such a nicety, that the thin edge of a knife could not be insinuated between the joints without a great deal of difficulty." And we learn from a note to that letter, that the gate of the Austin friars at Canterbury, the gate of St. John's abbey at Colchester, and the gate near Whitehall, Westminster, are executed in the same taste; and the platform on the top of the Royal observatory at Paris, which is paved with flint after the same manner, is adduced as a proof that the French have in some measure recovered the art. Flint is also often employed in the manufactory of glass, smalt, porcelain; and some of its lighter coloured and striped varieties are made use of for ornamental purposes. They take an excellent polish, and are not unfrequently manufactured into snuff-boxes, &c.

FLINT-*Slate*. The history of this fossil presents a labyrinth of blunders and confusion. On one hand it has been described under the names of well defined Wernerian species of rocks, such as horn-stone, trapp, &c.; on the other hand it has been jumbled together with various mineral substances, under the vague and unsystematic appellations of roche cornéenne, petrosilex, and particularly (by German mineralogical writers) under that of "hornschiefer," or corneous slate. This latter was applied by some mineralogists to the subject of this article; but by others it was indiscriminately given to hornblend-slate, to varieties of clay-slate, to mica, and to porphyry-slate; whence professor Werner, to prevent the same confusion that has been introduced into mineralogy, by the term "shorl," expunged that of hornschiefer, (though he had made use of it himself,) applying to the fossil in question the name of *kiesel-schiefer*, now generally adopted in Germany, and of which "flint-slate" is a literal translation. The just mentioned author has divided this species into two sub-species, *viz.* into common flint-slate, and Lydian stone. The latter has been considered by some as a mere variety of the former; but there are good reasons for keeping it distinct. See LYDIAN STONE.

Common flint-slate occurs generally of a dark grey colour, which has frequently an admixture of blue, of red, and of yellow; and these tints often pass over into each other, or are seen separately in the same fragments, as spots or stripes. The blood-red and brownish-red varieties are the scarcest. It is found massive and in rounded pieces; which latter have a smooth surface. Internally it is dull; now and then rather glimmering. In small fragments its fracture varies; it is sometimes splintery, and imperfectly conchoidal, and sometimes passes into even; the blackish-grey variety with the latter fracture approaches the Lydian stone. In large masses it manifests its slaty nature. Its fragments are angular and sharp, and but little translucid at the edges. It is brittle, and its hardness nearly the same as that of quartz. Another pretty constant character of flint-slate is its being traversed by veins of quartz, that are often of a greyish or reddish colour. Specific gravity, according to Gerhard, 2.860; according to Kirwan from 2.596 to 2.641. Those varieties of flint-slate that have been chemically examined are not fusible *per se*; nor do they much change their colour in the fire; the grey becomes rather lighter coloured, the black does not appear to be at all affected by the heat of the blow-pipe. Wiegleb's analysis of flint-slate from Fulda (in vol. i. of Chem. Annalen, where, however, it is called hornschiefer, and considered as of volcanic origin) has given the following result:

Silica	75.00
Lime	10.00
Magnesia	4.58
Oxyd of iron	3.54
Inflamm. particles	5.02
	98.14

Flint-slate appears to pass over into Lydian stone, into horn-stone, quartz, and particularly into clay-slate; so that when seen in small fragments, it is often difficult to seize its distinguishing characters. It is found in various parts of Germany, Bohemia, Silesia, in Bareuth, the kingdom of Saxony, the Hartz, Palatinate, Salzburg, &c.; and, according to Mr. Jameson, in various parts of the great tract of transition rocks in the south of Scotland. The geognostic relations of flint-slate are not well ascertained, and indeed it is difficult to assign it a proper place among the rocks. It is generally found in huge, cliffy, and craggy masses, particularly on granite and clay-slate, and more frequently as beds in transition, clay-stone, grauwacke, and grauwacke-slate. From the observations of some geologists it would appear that flint slate is, in many cases, to be referred to the transition rocks of Werner; and, according to Freiesleben, the specimens in Lasius's collection of rocks, which by this author are described as varieties of trapp, belong to the transition flint-slate; whence its occurring as angular fragments in grey-wacke, and as rounded pieces in the old red sand-stone can be no matter of surprize. Most frequently, however, it occurs in the shape of boulders, on plains, and in the beds of rivers.

FLINT is used, in our military service, for the purpose of affixing into a *vice* made at the top of the *cock* of a musquet, or pistol lock; so that when impelled against a piece of steel, called the *hammer*, it may strike fire, and ignite the gun-powder contained in a *pan*, concealed by the *hammer*, until the latter is forced backwards on a pivot, by the great force with which the *cock* strikes against it; when it not only produces fire, but, by its peculiar form, directs the sparks towards the *priming* in the *pan*.

Flints are easily adapted to this purpose; those great masses which are found chiefly in chalky soils, being broken by hammers, yield a number of wedge-like pieces,

of which the fides are trimmed to the proper width, and the backs brought into a proper form, which fhould be rather concave. This concavity is, however, very little attended to, but is of great fervice, fince it embraces the fcrew of the vice, and caufes the flint to retain a much firmer hold than when its back is made either ftraight, or convex; the latter is a great fault, but is commonly overlooked.

The proper fizes for flints are as follow; for a mufquet, one inch and five-eighths, for the length, with a width of an inch and a quarter; the thicknefs at the back one-third of an inch, and the tapering to be rather fudden than gradual, fomething like the end of a chifel. Such flints fit well in the *vice*, being previoufly laid in a bed of thin fheet-lead, or for want of it, in ftout leather. The edge of a flint, thus formed, is far lefs fubject to fplinter, than where the angle is more acute. It may perhaps be objected, that a thin edge ftrikes fire better than a thick one; but that will be for only a few rounds; whereas the thicker edge refifts better, and preferves an equable facility of fcintillating for a long time. All military men muft know that nothing is more adverfe to the operations of a regiment, than the neceffity (which too often occurs in confequence of the proper form not being fufficiently attended to) for men to quit their ranks for the purpofe of either hammering, or changing their flints. To the brave man fuch a neceffity is painful, as well as dangerous, while to the lefs refolute it ferves at leaft for a pretext to pafs into the rear, or eventually to relinquifh his poft altogether.

A carabine flint fhould be one inch and a quarter in length, by one inch in width; that for a piftol, fuch as is ufed among our military, ought to be rather more than an inch in length, by three quarters in width. In fixing them into the vice, great care fhould be taken that their left fides pafs down clear of the barrel, which they would otherwife hack very much, and be themfelves fubject to fplinter, while the cock itfelf might, by being unduly checked, be fnapt at its neck.

When flints have a curve, they fhould always be fo fixed in the vice, as to give the curve a downward direction; fince, in that way, they act more forcibly, and offer the greateft refiftance. Straight flints, after being fo far rounded as to yield no fparks, when their chamfered fides may have been uppermoft, may be again rendered ferviceable by being reverfed, fo as to bring their flat fides uppermoft. Soaking flints in water reftores them partially, probably by fupplying them with hydrogen, but in a very fmall degree, and that not permanently.

The beft flints are fuch as, when acted upon by fteel, produce ftrong lafting corrufcations, which emit a fulphureous fmell, and are fufficiently large to leave fome little ftain on tiffue paper, or on fine lint. Such will not only be found to yield a certain fire, but to break up admirably under the hammer employed to reduce them to fplinters, and to fit them for the foldier's ufe. On the contrary, however clear, black, and firm a flint may appear, if its fparks are not vivid, and highly fulphureous, it ought to be at once thrown afide.

The hardeft flints being generally the beft, experiments were made with agates, cornelians, &c. all of which produce beautiful fparks, but, being extremely brittle, could not be brought into general ufe; however, in fituations where they are obtainable, and where flints are not to be had, they become valuable fubftitutes. Various attempts have been made to produce flints by means of compofition; but fuch have always proved vitreous, and confequently weak both in fubftance, and in the production of fparks. We cannot conclude this article without ftrongly recommending, that more attention be paid at our arfenals to the rejection of flints of defective form and quality.

Flints are generally packed in fmall cafks, called half-barrels, each of which contains,

	Number		qrs.	lbs.
Mufquet flints	2000	weighing	2	14
Carabine do.	3000		2	10
Piftol do.	4000		2	15

The tonnage of this article is computed at 28 kegs of mufquet-flints to occupy 18 cwt. and 10 kegs of piftol-flints to occupy 3 cwt. 2 qrs. which our readers cannot fail to obferve by no means correfponds with the foregoing table of contents.

Flints, in the *Glafs-trade*. The way of preparing flints for the niceft operations in the glafs-trade is this. Choofe the hardeft flints, fuch as are black and will refift the file, and will grow white when calcined in the fire. Cleanfe thefe of the white cruft that adheres to them, then calcine them in a ftrong fire, and throw them, while red-hot, into cold water; wafh off the afhes that may adhere to them, and powder them in an iron mortar, and fift them through a very fine fieve; pour upon this powder fome weak aqua fortis, or the phlegm of aqua fortis, to diffolve and take up any particles of iron it may have got from the mortar; ftir this mixture feveral times, then let it reft, and in the morning pour off the liquor, and wafh the powder feveral times with hot-water, and afterwards dry it for ufe. You will thus have a powder for making the pureft glafs, as perfectly fine and faultlefs, as if you had ufed rock cryftal itfelf. Cramer's Art of Affaying Metals, p. 438.

The wafhing off the ferruginous particles with aqua fortis is not neceffary when the glafs intended to be made is to be tinged with iron afterwards; but when meant to be a pure white, this is the method that will fecure fuccefs.

Flints, the fmall, fharp, hard, vitrifiable ftones which often abound in foils of the more thin, poor kinds.

Flints, *oil* or *liquor of*, a name given by fome to a preparation made of four ounces of flints, calcined and powdered, and mixed with twelve ounces of falt of tartar; thefe being melted together in a large crucible, by a ftrong fire, run into a glafs, which quickly and ftrongly attracts moifture from the air, and is entirely foluble in water, except a very fmall portion of earthy matter; this glafs, being afterwards powdered and fet in a cellar, runs into an oil per deliquium; with this and the calx of any metal is prepared one of the metallic vegetations. If any acid be added to the liquor of flints, fo as to faturate the alkali, the flint, which was kept diffolved in water by means of this alkali, will be now precipitated in the ftate of a fine earth, which earth is entirely foluble by acids.

Flint *Walls*. See Wall.

Flint *Nodules*, in *Geology*, are a phenomenon of a curious and important kind, when their regular difperfion through the chalk ftrata are taken into confideration, as well as the fingular and fomewhat regular fhapes which they affume. The great affemblage of chalk ftrata which form the uppermoft but two of the affemblages of ftrata in Britain, as far as is yet known, (*viz.* the London-clay and Bagfhot-fand,) abounds with thefe nodules in about the upper half thereof, called the upper or flinty chalk, while the under part, called the lower or hard chalk, has few if any flints occurring in it, and thefe, at its upper part, if fuch do occur. It is well afcertained, that none of the chalk ftrata are entirely free of minute grains of filiceous or gritty matter in them, whence the ufe of chalk or whiting in fcowering tin, filver, and other veffels arifes; and modern obfervations by Mr. Smith and his pupils have fhewn, that where the layers of

flints moſt abound, or are neareſt together, as they are near to the top of the whole ſeries, that there the intervening beds of chalk are moſt *free* or ſoft, as well as the whiteſt, and that from theſe ſituations it is, that the writing chalk uſed by carpenters, &c. and the beſt for the manufacture of whiting for lime for the plaſterer's uſes, or for chalking land by the huſbandmen, are taken. It has further been obſerved, that as the flints decreaſe in quantity, in deſcending the chalk ſeries, that more ſiliceous grains appear in the chalk itſelf, until the flints ceaſe altogether, and the lower-chalk commences; which lower chalk is much harder, more like lime-ſtone, and is more ſiliceous, which properties ſeem to render it preferable for the common purpoſe of mortar-making, than the ſofter chalks. This hard or inferior chalk, uſed for lime-burning in Bedfordſhire and the adjoining counties, is called hurlock; and it is obſerved, that the beds of this hard chalk become more hard and compact in deſcending the ſeries, as was a few years ago viſible to travellers in the cutting of the new road down Ruddle-Hill, a mile from Dunſtable, and as may again be ſhewn, if the tunnel which has been propoſed under the old road for avoiding the inconvenient bend occaſioned by the new one, ſhould be carried into effect. The hard chalk or hurlock continues to increaſe in its ſiliceous qualities until near the bottom of the ſeries, where it becomes a free-ſtone, which is in great repute there, under the name of Totternhoe-ſtone, which has a ſharp and fine grit, and inſtead of being lime-ſtone, poſſeſſes the properties of a *fire-ſtone*, under which denomination the ſtone of this ſtratum is brought to the metropolis from Ryegate, Godſtone, and other places on the ſouthern ſkirt of the North Downs of Surry. Thus it appears, that ſiliceous or flinty matter abounds in the chalk, through the whole ſeries, from the ſand ſtrata which lie above it (at Croydon), to the ſand ſtrata which lie below it (at Ryegate); but it is in the upper part of the chalk ſeries collected into nodules and layers of flint, and in the lower part of the ſeries is diſtributed in the maſs of chalk.

It ſeems probable, from the obſervations of Mr. Parkinſon, and other late obſervers, that the flint nodules of the chalk ſtrata, or great part of them, owe their origin, or rather perhaps occupy the place of the Alcyonium and others of the zoophytic tribes of the primitive creation. The vaſt number of hollow tubes in flint, which we meet with in the chalk pits at Harefield, near Rickmanſworth, Herts, and other places, though often miſtook for petrified *bones*, ſeem to us to be remains of the coralline tribe. *Echini* are often found among the flint nodules of the chalk ſtrata, ſome of them large and rather of a rude ſhape, compared with the delicate workmanſhip obſervable on many of echinus; this kind are found in vaſt numbers in the chalk-pits about Brandon in Norfolk, and are uſed in budding walls and houſes, in a neat and very ſingular ſtyle.

FLINTSHIRE, in *Geography*, a county in North Wales, bounded on the ſouth and weſt by Denbighſhire; on the north by the Iriſh ſea; and on the north-eaſt is ſeparated from Cheſhire by the eſtuary of the Dee. At an early period this diſtrict formed a portion of the country to which the Romans gave the appellation of Ordovicia; the inhabitants of which ſo eminently diſtinguiſhed themſelves in their pertinacious reſiſtance to the Roman arms. Subſequent to the Romans leaving the iſland, it long conſtituted the territory known to the Britons by the name of Deheubarth; and ſeveral ſtrong caſtles ſtill remaining, ſhew it was formerly a ſcene of ſanguinary contention. In the time of Henry VIII, when Wales was incorporated with England, this was made one of the ſix counties of North Wales. This county extends in length 33 miles, and in breadth from 8 to 9, containing about 160,000 acres of land, of which, according to the report to the Board of Agriculture, only 20,000 are in an arable ſtate, 116,000 under paſturage, and the remainder in a ſtate of waſte. The principal rivers are the Dee, which riſing in Merionethſhire, after running through Denbighſhire, waſhes this county, and is navigable from Cheſter to the ſea. The Clwydd has its ſource in Denbighſhire, and, running in a northerly direction, is joined by the Alan below St. Aſaph, and falls into the Iriſh ſea. It is alſo watered by the Sevion, the Wheeler, and a few ſmaller ſtreams. The face of the country is much leſs diverſified than any other Welſh county. A ridge of low hills riſes abruptly on the north-eaſtern part of the county from the Dee, and, running parallel with that river, terminates at the ſea. The vale of Mold is a rich level country, and the vale, or rather valley of Clwydd, has has been long celebrated for its pictureſque beauty. The northern part is champagne, and abounds with corn; the vallies conſiſt of an argillaceous ſoil, and are productive in graſs. The cattle are ſmall, but conſidered excellent milchers. Quantities of honey are annually produced, which the inhabitants manufacture into a kind of wine called Metheglin. The hills are barren, but are internally rich, containing free-ſtone, lime-ſtone, coal, lead, copper, and calamine, the ores of which are ſmelted, and the metals exported viâ the port of Cheſter. The county politically is divided into five hundreds, *viz.* Coleſhill, Maylor, Mold, Preſtayn, and Rhyddlan, compriſing one city, St. Aſaph, one borough, Flint, and four other market towns, *viz.* Caerwys, Caergwrle, Mold, and Holywell; and twenty-eight pariſhes, 23 of which are in the dioceſe of St. Aſaph, and five in that of Cheſter. By the returns made under the population act to parliament, in 1801, the number of houſes was 7585, and inhabitants 39,622; out of which number it appeared 10,332 were occupied in the labours of agriculture, and 6989 employed in trade. Many of the latter find employment in the mines and ſmelting-houſes, and others in the linen trade, a manufactory of which was, by the patriotic exertions of Mr. Fitzwilliams, introduced into the county, and has ſince ſpread, and is at preſent in a flouriſhing ſtate. The county is repreſented by one member in the Britiſh ſenate.

Flood

FLOOD, a deluge or inundation of waters. See DELUGE.

FLOOD is also used in speaking of the tide. See TIDE.

When the water is at lowest, it is called flood; when rising, young, or old flood; when at highest, high flood; when beginning to fall, ebb-water.

FLOOD-*mark*, the mark which the sea makes on the shore, at flowing water, and the highest tide: it is also called high-water mark.

FLOOD *Sand*. See SAND.

FLOOD-*gate*, among *Engineers*, signified a gate or sluice which can be opened or shut at pleasure to retain or give passage to the water of a river liable to be swollen by floods. Flood-gates are necessary in many situations upon rivers where the water is retained for the service of mills, canals, navigations, docks, &c.; in these only a certain quantity of the stream can be employed, and the surplus in time of a flood must be suffered to escape by another passage. For instance, in the case of mills upon a large and rapid river, the stream of water is intercepted by a weir erected across it, and penned up the proper height to obtain a sufficient fall for the mill, which is situated by the side of the river, with a channel leading from above the weir, to convey the water to the mill, whilst another conducts it into the river below the weir. In ordinary times this arrangement is sufficient, for whenever the mill is not in action, the water which would otherwise pass through it, flows over the weir, and escapes into the river below. Now if the sudden falling of rain, or melting of snow, causes a flood in the river, it often happens that the length of the weir is insufficient to vent the torrent of water coming down; and without some contrivance answering the purpose of a flood gate, to give passage to the water, it becomes penned up many feet above the crown, or highest level of the weir, inundating the lands adjacent to the channel, above the weir. If the river is provided with a proper flood-gate, it acts, when open, in the same manner as removing a part of the weir, and allows the water to pass down quietly without rising much above the level which is common in ordinary times. From this, the use of a flood-gate will be comprehended; navigable rivers, which are penned up to form locks, require flood-gates, which are applied in the same manner as before-mentioned.

Flood-gates may be constructed in various forms; but it is indispensable that they should be capable of being opened or shut during the time when a pressure of water is acting against them. Small gates are always made to slide up and down in a groove in the manner of a sluice; some very considerable rivers are furnished with a number of such small draw-gates, which open a great extent of water, when drawn up. In the most extensive works it is necessary to make use of a different kind of gate, which can be opened or shut with greater ease than a number of shuttles, and which will lay open a more extensive passage; for in violent floods it is not uncommon for large trees, bushes, hay ricks, thatched roofs of low buildings, &c. to be brought away by the torrent; and if the flood-gates have any obstruction, these matters accumulate before the passage, and, when the flood lasts long, frequently choak up the gate, and the water overflows its banks. To avoid such accidents is the study of the engineer in constructing works of this kind; the late Mr. Smeaton designed several flood-gates, in which the pressure of the water was balanced, so that the gate at any time could be opened or shut with ease, even while the pressure of the water was acting against it on one side only. *Figures* 5 and 6 of *Plate* XV. *Miscellany*, is a plan, and *fig.* 2. an elevation of this contrivance; A A B B represents a channel made through the weir, or, if more convenient to suit the local circumstances, it is made by the side of the river, leading from above the weir to below it: this channel must be substantially built in masonry to resist the violent action of the water rushing through it when the gate is opened; in some convenient part of this passage a stout beam C is placed across the bottom, and another, D, across the top, both firmly bedded in masonry; these support the gudgeons of the vertical axis E of the gate F F. When this gate is turned so as to present its edge to the current, the water has free passage by it, and on the other hand, when it is placed perpendicularly across the channel, the whole of the water is detained: the axis of the gate is placed so as to pass very nearly through the centre of pressure of the superficies exposed to the action of the water; and as the pressure of the surfaces on each side of the

axis act to turn the gate in contrary directions, they balance each other, and the gate may be turned with scarcely any other resistance than the friction of its gudgeons. The gate must necessarily be framed exceedingly strong to bear the great weight of the water acting against it, without yielding. G, H, are two ground-cills firmly bolted down upon the floor of the conduit and the piles which are beneath it; one of the arms of each of these cills support the gate when shut, and the other arms sustain it when open, as is clearly shewn by the figure; these must be very firmly fixed to avoid any danger of the gate removing them; one of the upright sides of the gate is supported by falling into a recess made in the masonry of the conduit, and to keep the other side of the gate up to its cill, a lever, called a vallet, which is in the form of a triangle I K, and moves upon a vertical axis placed in a recess in the masonry so as to be out of the way of the gate's motion, when placed in the position at *fig.* 5, leaving the gate at liberty to open; in the other position it acts as a lever to close the gate, being drawn tight by tackle, and afterwards lashed by a small line to the beam D. The gate is retained shut, but can be opened instantaneously by cutting the line; and as the gate is made rather larger on the side of the axis where the vallet is placed, that it may have a tendency to open when released by the preponderating pressure on one side. The gate in question is 15 feet in height, and the same in breadth; when open, it allows two passages of 15 feet by 6 feet 3 inches in width; the gate is to be shut by the application of a capstan and blocks, for which purpose eye-bolts are provided on the proper points of the gates and beam D.

This gate, though very proper for large rivers where a watchman must be in constant attendance to open and shut it when necessary, is not so applicable as a common sluice to a small mill-dam, where, if a sudden flood occurs in the night, the miller must rise to open the gate; and, unless he constantly attends to shut it when the flood subsides, the mill-dam may be emptied and the water lost, which he would wish to reserve for the ensuing day. Great complaints are frequently made in the country of lands being overflowed in the night when the miller is not in the way to open his flood-gate; to remedy this a self-acting flood-gate would be desirable, and we beg leave to suggest the following. Let A A, *fig.* 7. be a gate similar to the one before mentioned, but of smaller dimensions, and poised upon a horizontal axis passing rather above the centre of pressure of the gate, so as to give it a tendency to shut close: *a a* is a lever fixed perpendicular to the gate, and connected by an iron rod with a cask *b* floating upon the surface of the water, when it rises to the line B D, which is assumed as a level of the weir or mill-dam B C E F, in which the flood-gate is placed; by this arrangement it will be seen, that when the water rises above the dam, it floats the cask, opens the gate, and allowing the water to escape until its surface subsides at the proper level B D; the cask now acts by its weight, when unsupported by the water, to close the gate and prevent leakage; the gate should be fitted into a frame of timber H K, which is set in the masonry of the dam, the upper beam H of the frame being just level with the crown of the dam, so that the water runs over the top of the gate, at the same time that it passes through it; to prevent the current disturbing the cask it is connected by a small rod *e* at each end to the upper beam H of the frame, and jointed in such a manner as to admit of motion in a vertical direction.

This flood-gate would be very useful in mill-dams of small dimension, which are therefore liable to be suddenly overflowed, for being self-acting, it requires no attendance, and from its simplicity is not very liable to be deranged, as before mentioned; for large rivers the principal object is, to open a great extent of water-way, which will admit the passage of large bodies brought down by the stream; Mr. Smeaton's gate above mentioned, as the axis is always in the channel, would be liable to be choaked by trees, &c.; for this reason large sluices or shuttles are very generally adopted, though the great power and expensive machinery required to raise such gates are an objection.

A flood-gate lately erected by Mr. Bramah is the most perfect in this respect of any that we have met with; it is raised (on the hydrostatic principle which he has so successfully applied to many other useful purposes) with such facility, that a passage 19 feet wide, and 10 feet high, can be opened by one man in 15 minutes, and this when the pressure of 10 feet of water is acting on one side only. *Fig.* 8 is an elevation of this gate, and *fig.* 9. an horizontal section; A, A, represent two large beams which are partly received into the masonry of the conduit; the lower ends are framed into a strong ground-cill B, and the upper ends connected by a framing; this forms a frame in which the gate rises and falls: it is guided in its motion by two iron plates *a, a*, bolted to the sides of the gate, forming a groove, as shewn in the plan. Two square pieces of cast iron, denoted by *b, b*, and the dark shading in the plan, are bolted against the inside surfaces of the beams A, A, and received into the grooves of the gate, to confine it to move in a vertical direction: these pieces of iron have cylindrical chambers through them, as shewn by the small white circles in the plan, to admit two polished iron cylinders *d, d*, attached to the end of the upper rail D D of the ornamental framing on the top of the gate; a close fitting is made round the cylinders *d, d*, by leathers confined with screws to press against them at the top of the iron barrels, so that no fluid can pass out of the chamber in the barrels *b, b*; *e, e*, in the plan, are two small pipes communicating with the chambers at the bottom of each barrel, and these pipes are united at *f*, proceeding to a pump, by which water is injected into the two chambers together; and as this fluid is incompressible, it follows that the cylinders *d, d*, must be forced out of their respective chambers raising up the gate. As the area of the pump is much less than that of the cylinders, and as it supplies two of them, it follows that the motion of the piston of the pump will inject such a quantity of water as, when distributed into the two chambers, produces a very small protrusion of the cylinders; it is on this principle of the differences of the two motions that the power is gained: the area of the pump in the present instance is .7854 of a square inch, and the cylinders about 7.07 square inches, or nine times as much; by this means a power is gained in the two cylinders equal to 18 times the force exerted upon the piston of the pump, which being moved by a lever multiplying the power ten times, the power of a man applied to the pump is increased 180 times; so that a weight of 100lbs. applied to the lever, will raise 18,000 lbs. on the piston rods.

The pump may be placed at any convenient distance from the gate, a small copper tube only half an inch diameter conducting the water into the cylinders in many situations this will be extremely convenient, as it obviates the necessity of an expensive scaffold or framing over the gate, which is indispensable in other sluices to support the labourers and the machinery for drawing up the gate; the pump is explained by *figs.* 10. and 11. on a much larger scale than the other parts; *h* is a cistern containing water, and *i* the pump-barrel fixed perpendicular in it; the plunger or piston *g* is solid, and leather packed round it in a manner something

When they are dowelled, they may be nailed on one or both edges, though one edge only is necessary; and in the best dowelled work there are no brads or nails seen whatever, the outer edge being fastened by driving the nail obliquely through the wood, without piercing the upper surface; so that the floor, when planed off, appears without blemish.

In laying boarded floors, the boards are sometimes laid one after the other; or otherwise one is first laid down, then the fourth, leaving an interval somewhat less than the breadth of the second and third together. The intermediate boards are next laid in their places, with an edge of the one upon the edge of the first board, and an edge of the third upon the inner edge of the fourth, and the two middle edges together, which will form a ridge; to level which, two or more workmen jump upon it, till they have made the under surface coincident with the joists, then they are nailed down in their places. The operation is called folding floors, and the boards are said to be folded. This mode is only taken when the boards are not sufficiently seasoned; or suspected to be so. In order to make close work, it is obvious that the two edges forming the joint of the second and third boards must make angles, with the faces, together less than two right angles, or each one of each board less than a right angle. The seventh board is fixed as the fourth, and the fifth and sixth inserted as the second and third, and so on till completed. In this kind of flooring the headings are generally square or splayed.

When floors are dowelled, the regulating line for the centre of the dowels should be drawn from the lower side, which, as has been observed, ought to be straightened on purpose. The distances to which the dowels are set, are from six to eight inches, generally one over each joist, and one over each inter-joist.

When it is necessary to have a heading joint in the length of the floor, it should always be upon a joist; one heading joint should never meet another. In dowelled floors the heading points are always plowed and tongued.

In common floors the boards are adzed on the lower side, in order to bring them to a thickness between rebated edges. In doing this, great care should be taken so as not to make them too thin, which is frequently the case; they must then be raised with chips, which is a very unstable resistance to a pressure upon the floor. The manner of measuring floors is by squares of ten feet on each side, so that taking the length and breadth, and multiplying them together, and cutting off two decimals, the content of a floor in squares will be given. Thus 18 by 16 gives 288 of 2 squares and 88 decimal parts.

Floors, *Earthen*, are commonly made of loam, and sometimes, especially to make malt on, of lime, and brook-sand, and gun-dust, or anvil-dust from the forge; the whole being well wrought up and blended together with blood. The siftings of lime stone have also been found highly useful when formed into floors in this way.

Ox-blood and fine clay, tempered together, sir Hugh Plat says, make the finest floor in the world. The principal object in constructing floors of this nature is that of blending and incorporating the different substances in a full and perfect manner for some time before they are laid; and when that is done they should be repeatedly beaten down and rendered perfectly smooth and even.

The manner of making earthen floors for plain country habitations is as follows. Take two-thirds of lime, and one of coal ashes well sifted, with a small quantity of loam clay; mix the whole together, and temper it well with water, making it up into a heap; let it lie a week or ten days, and then temper it over again. After this, heap it up for three or four days, and repeat the tempering very high, till it become smooth, yielding, tough, and gluey. The ground being then levelled, lay the floor therewith about 2½ or 3 inches thick, making it smooth with a trowel: the hotter the season is the better; and when it is thoroughly dried, it will make the best floor for houses, especially malt-houses.

If any one would have their floors look better, let them take lime made of rag-stones, well tempered with whites of eggs, covering the floor about half an inch thick with it, before the under flooring is too dry. If this be well done, and thoroughly dried, it will look, when rubbed with a little oil, as transparent as metal or glass. In elegant houses, floors of this nature are made of stucco or of plaister of Paris beaten and sifted, and mixed with other ingredients. Well wrought coarse plaster likewise makes excellent safe upper-floors, for cottages, out-houses, &c. when neatly spread out upon good strong laths or reed. See Plaster-*Floor*.

Floor *of a ship*, strictly taken, is only so much of her bottom which she rests on, when aground.

Such ships as have long, and withal broad floors, lie on the ground with most security, and are not apt to seel, or tilt on one side; whereas others, which are narrow in the floor, or, in the sea-phrase, *cranked by the ground*, cannot be grounded without danger of being over-turned.

Floor *timbers*, in a *Ship*, are those parts of a ship's timbers which are placed immediately across the keel, and upon which the bottom of the ship is framed; to these the upper parts of the timbers are united, being only a continuation of floor-timbers upwards.

Floor, in *Mining*, or sole, thill, or pound stone, signifies the bottom of the work in a mine, or in coal-mining, the stratum immediately under the coal-seam; which if soft, the upper part of it for six or eight inches in height generally is "holed in," as the colliers call it, that is, the same is picked out in order to undermine or loosen the coal, but if the floor be hard, as clunch is, the holeing or picking is then made in the bottom or some inferior bed of the coal itself, in order to under-go or give room for wedging down the blocks or webs of coal. In examining and comparing the sinkings of the numerous coal-pits in Derbyshire and Nottinghamshire, Mr. Farey lately discovered, what seems likely to prove a general and important geological fact, *viz.* that the floor of every coal is a fire-clay, more or less thick, more or less perfect in its infusible property, and more or less indurated; sometimes being in a soft or ductile state, when it is called floam, spavin, fire-clay, pipe-clay, (if white,) potter's-clay, brick-clay, &c. at others, in an indurated or almost stony state, but which it quickly loses and falls to clay, on exposure to the atmosphere, in which case it is called clunch, which is the name that the floor of coal most generally bears. This new fact appears to throw a great degree of light on the new theory of the formation of coal, near the end of our article Colliery, by rendering it probable that the growth of the subaqueous beds of vegetables there spoken of were produced by this peculiar substance as their soil or pabulum.

Floor, a superficial measure of 400 square feet or docking, is a square whose side is 20 feet, and occurs in the facing of the fen-banks, and in other works on the fens of Cambridgeshire and Norfolk, &c.

Floor, a solid measure of 400 cubit feet, or a superficial floor, one foot thick, used in measuring the pits dug to obtain earth for forming the banks against the tide or rivers in the fens on the eastern coast (Smeaton's Reports, vol. i. p. 330.)

Fluor

FLUOR, in *Physics*, &c. denotes a fluid; or, more properly, the state of a body, which was before hard and solid, but is now reduced, by fusion of fire, into a state of fluidity.

Gold and silver will remain a long time in fluor, maintained by the intensest heat, without losing any thing of their weight. See GOLD, FIXITY, &c.

The word fluor is applied to signify the habitual fluidity of any substance, or that property by which a substance cannot be rendered solid, and is employed as an epithet to distinguish such substances from others of the same kind, but which are habitually solid, or which may be rendered solid.

FLUOR, in *Mineralogy*, a species of the calcareous genus, being a combination of lime and fluoric acid, and known by the chemical appellation of *fluate of lime*. The more familiar names under which it passes in most countries are *fluss* and *fluor*, denoting the use to which it is frequently applied as a flux of various ores. Beside these, there are a variety of other names that have originated in the similarity of its colours, (particularly those of the fluor-spar,) to the beautiful tints of several of the stones called precious; such are *false emerald, hyacinth, topazes, beryl, chrysolite*, &c. Indeed there is no mineral that may equal fluor in the varied beauty of its hues; the suite of its colours is almost sufficiently comprehensive to be formed into a chromatic scale. It is reserved for nicer chemical observation to discover the nature of this variously modified colouring principle, which is more fugacious in fluor than in most other minerals, but probably always corresponding with the nature of the metallic substances that accompany fluor in the bowels of the earth.

Fluor has been divided by Werner into three sub-species, namely, *earthy, compact*, and *spathose fluor*. The first, also known by the name of the phosphorescent *earth of Marmarosh*, was classed with the fluates of lime on the authority of Pelletier; but the late analytical experiments of Klaproth, who found 32 parts of phosphoric to two of fluoric acid, shew the necessity of restoring it to the phosphates of limes, to which it was first referred! Mr. Jameson appears to have had his doubts respecting this substance; he does not describe it as a sub-species of fluor, nor does he enumerate it among the phosphates of lime. See PHOSPHORITE.

1. *Compact fluor.* This is rather better understood; but it appears that mineralogists are very apt to confound the terms "compact" and "massive" also in speaking of fluor: whence massive fluor spar has been described as Werner's compact fluor. This latter occurs but rarely, having hitherto been found only at Stollberg and Strasberg in the Hartz, and at Yxsiö and Norberg in Sweden, to which habitats we may perhaps add Schlackenwalde and Kriman in the Saatz circle of Bohemia, and Schwarzleogang in Salzburg. The following external characters appear the most important.

Its colour is generally light greyish-green, passing sometimes into greenish-white, sometimes into blueish-grey, approaching to verdigris green, and it is also found reddish. Not seldom several of these shades are mixed in spots in one and the same fragment, now and then with the addition of accidental yellowish and brownish spots.

It occurs massive only. Fracture more or less even, approaching sometimes to flat conchoidal, sometimes to splintery, even to foliated. The fragments are indeterminately angular with pretty sharp edges, and more or less translucent in the same piece.

It is feebly glimmering, almost dull. Half-hard, scarcely scratched by fluor spar, brittle, easily frangible. Its specific gravity, if Kirwan's compact fluor be the same as the one here described, is 3.120 to 3.165.

This sub-species, to a superficial observer, appears sometimes like horn-stone, sometimes like compact lime-stone; but the above external characters (to which may be added the physical one of its shewing a weak phosphorescence when laid on ignited coal) keep it sufficiently distinct. Its geographic situation has been given above. Its geognostic situation at Stollberg is in a vein, in greywacke; it is found with fluor spar (its constant companion), some copper pyrites and barytes. At Kriman in Bohemia it was found by Dr. Reuss in gneiss, in which it is sometimes seen as thin laminæ between the layers of quartz and feldspar.

It is, together with fluor spar, made use of as a flux.

2. *The sparry fluor*, or *fluor spar*, which, besides the above-mentioned general names, is also known under those of *cubic fluor, glass fluor, phosphorescent spar, spath vitreux, spath fusible*, &c.

Its principal colours are, 1. *White*, such as greyish, greenish, yellowish, and reddish-white, passing into 2. *Red*, particularly rose red of various intensity, carmine. 3. *Grey*, greenish, yellowish, smoke, and pearl-grey. 4. *Blue*, lavender, azure, smalt, sky-blue, Prussian and violet-blue, the two latter appearing sometimes nearly black. 5. *Green*, verdigris, seladon, mountain, emerald, grass-apple, leek, pistachio, and olive green. 6. *Yellow*, wine, wax, honey yellow. 7. *Brown*, yellowish, and clove-brown. All these colours will frequently pass into each other, and even those least related to each other are sometimes seen together in the same specimens in spots and flakes, and in stripes that often appear like some kinds of alabaster, whence Rome de l'Isle called a variety of fluor, *alabâtre vitreux*. The colouring matter of some of them is very fugacious, especially that of the sky-blue variety, which is often seen to fade merely by being exposed to the atmospheric air. Of the above colours, the white and violet blue are the more common.

Fluor spar is found massive and disseminated, and most commonly crystallized, but it has not been observed, except in one instance to be mentioned hereafter, in those imitative shapes, (such as dentiform, branched, stalactitic,

&c.) in which the carbonates and sulphates of lime, and other crystallizable earthy substances so frequently occur.

Its primitive form is the octaedron. As to the determination of the integrant molecule some difficulty has arisen. The octaedron, we know, cannot be sub-divided into solids of the same form; the last term of mechanical division we arrive at is that into other octaedrons accompanied by tetraedrons; six of the former and eight of the latter being disposed in such a manner as to form in all directions acute rhomboids. If we imagine either all the octaedral or all the tetraedral particles removed, those of the same kind that remain will still be in exact connection by means of their edges. Of the latter circumstance Haüy has ingeniously availed himself to reconcile this resolution of the octaedral crystal into two kinds of solids, with that principle according to which all the integrant molecules of a crystal must be necessarily similar. He supposes that, could we cast a look into the primary construction of the octaedral crystal, and sub-divide it to the utmost limits, we should find the whole substance pervaded either by tetraedral or octaedral vacuities; if the former, the whole would be composed of octaedral elementary particles, if the latter, the tetraedron would exclusively constitute the integrant molecule. Now as, according to Haüy's doctrine, this molecule is constantly either the parallelopiped, or the triangular prism, or the tetraedron, analogy has in this case decided in favour of the tetraedron, which is now considered as the integrant molecule of fluor, instead of the octaedron. It was Werner who first observed the tetraedral and octaedral fragments which result (according to his terminology) from the fourfold cleavage presented by the foliated fracture of fluor.

The principal forms of the crystals of fluor-spar, with their modifications, considered, not according to their origin, but to the manner in which they present themselves to the eye, are the following:

1. The *perfect cube* (*chaux fluatée cubique*, Haüy.) It is sometimes elongated; passing from the cubic form into that of a rectangular four-sided prism, generally with two of its lateral planes narrower. We have seen specimens of the latter variety from Cumberland; it is also found at Schemnitz and Nertshinsk.

2. Cube with all the edges truncated (*chaux fluatée cubo-dodécaèdre*, Haüy).

3. The preceding with planes of truncation so much increased that the rhomboidal or garnet-dodecaedron is formed (*chaux fluatée dodécaèdre*, Haüy.)

4. Cube with all its edges bevilled (*chaux fluatée bordée*, Haüy).

5. The preceding, with bevilling edges so much enlarged as to convert each plane of the cube into four triangular planes (*chaux fluatée hexatétraèdre*, Haüy). What has been described as perfect cube with convex planes, we suppose to be this modification indistinctly formed.

6. Cube with all its solid angles flatly acuminated by three planes, placed on the lateral planes of the cube.

7. Cube having its angles acuminated by six planes, placed on the lateral planes. We do not know where the preceding and this variety occur; Emmerling informs us, that in the latter the six acuminating planes sometimes completely engross the planes of the cube.

8. The cube truncated at all its solid angles (*chaux fluatée cubo-octaèdre*, Haüy.) If the triangular truncating planes do not meet, the planes of the cubes are octagons; if they meet exactly, those planes are squares; if all the truncating planes encroach on each other these become hexagons, while the planes of the cubes remain squares; when they encrease still more the

9. *Octaedron*, with six truncated angles, is formed; in which the truncating planes are the six planes of the cube; in the same manner as the truncations at the eight angles of the cube N° 8. are the eight planes of the octaedron. When the truncating planes of the modification N° 8. enlarge so much as to cause the faces of the cube entirely to disappear,

10. The perfect octaedron, or double four-sided pyramid, is formed (*chaux fluatée primitive*, Haüy.)

11. Octaedron with truncated edges (*chaux fluatée emarginée*, Haüy.)

12. Octaedron with both angles and edges truncated.

13. The elongated octaedron with four broader and four narrower planes, terminating in a ridge.

No. 1. is by far the most common of all the modifications of crystallized fluor spar. No. 3. is very rarely met with; it was found by M. Subrin between Breuil and Charecey on the way to Chalons. Of No. 4. the most interesting varieties occur in Cornwall. From the geometrical figure in plate 73, of that useful work "British Mineralogy," it appears, that Haüy's chaux fl. bordée occurs in Cornwall, with the eight angles truncated, parallel to the octaedron, by which a crystal of 38 faces is formed. Of No. 10, the perfect octaedron, the most beautiful variety is the rose-coloured one, found in the neighbourhood of Mont-Blanc. It also occurs in beautiful crystals in England, on Mount St. Gothard &c. and Mr. Sowerby is, we suppose, the first who has noticed the small violet variety of this modification found in Aberdeenshire.

To the above may perhaps in future be added the following unusual modifications. 1. The *tetraedron* with faintly truncated edges, mentioned by Mr. Mohs as existing in the collection of Mr. Vonder Null: the truncating planes are stated to correspond to those of the cube. 2. The rhomboid (one of the forms which fragments of fluor-spar frequently exhibit, and which may be considered as an octaedron, with two tetraedrons applied to two of its opposite planes) is said to have been found as crystal. The third, mentioned by Emmerling, is the double eight-sided pyramid, acuminated at both extremities by three planes placed on the alternate lateral edges. It is said to have been found in Saxony, and is in the collection of Count Wrbna at Vienna.

The crystals of fluor spar are of various size: the perfect cubic is seen from five inches square to extremely minute, and scarcely distinguishable. They are found distinct and aggregated in various directions; sometimes globularly aggregated. Their surface is generally smooth and splendent; but sometimes perfectly dull. They are not seldom covered by an opaque crust of various colours, particularly blueish-green; often they are drusy, and sometimes ornamented with a beautiful golden and pavonine tarnish: of which latter we have a fine specimen before us. Internal lustre splendent, sometimes simply shining, according to the various degrees of perfection of the foliated fracture; it is vitreous, rather inclining to pearly; in some varieties even an adamantine lustre has been observed.

Fracture more or less perfectly foliated, almost always straight, seldom curved-foliated, sometimes approaching to vitreous; it presents a four-fold equiangular cleavage.

The form of the fragments has been mentioned in fpeaking of the integrant molecules. The maffive is generally feen in granular diftinct concretions of various bignefs; and fometimes it appears in columnar concretions, and radiated, interfected by curved lamellar diftinct concretions.

Degree of tranfparency according to the differences in the colour and fracture; fome varieties, particularly the white or colourlefs, perfectly tranfparent; others entirely opaque; moft commonly it is femi-tranfparent.

Its hardnefs is greater than that of calcareous fpar; but it is fcratched by iron; it is brittle, eafily frangible, and not very heavy; its fpecific gravity is,

3.092 (from Stollberg) } Gellert.
3.148 (from Freiberg) }
3.156 to 3.184. Mufchenbroeck.
3.175 (the green var.) Blumenbach.
3.200 to 3.700. Gerhard.

Other phyfical characters are its phofphorefcence when laid on ignited coal; the fky and violet-blue and green varieties have been obferved to emit the moft vivid phofphoric light. The variety from Siberia, called chlorophane, when put on ignited coal, does not decrepitate, but emits a beautiful emerald green light, which has procured it its name. A flight phofphorefcence is likewife obferved when two fragments are rubbed againft each other in the dark.

As chemical characters of fluor-fpar, we have to mention its decrepitation before the blow-pipe, (which, however, is not the cafe with the Siberian chlorophane,) and fubfequent lofs of colour, and its melting, (particularly with addition of borax or phofphoric acid,) into a greyifh-white enamel; as alfo its emitting fuffocating white vapours (fluoric acid) when acted upon by fulphuric acid.

The conftituent part of fluor-fpar, according to Scheele, the celebrated difcoverer of a peculiar acid in this mineral, were ftated to be,

Lime	57
Fluoric acid	16
Water	27

After him, Wenzel, Richter, and but lately Klaproth, have analyfed this fubftance, and obtained the following refults.

Fluoric acid	$32\frac{1}{4}$	
Calcar. earth	$56\frac{1}{2}$	
Iron and alum earth	$10\frac{1}{8}$	
	100	Wenzel, 1783
Fluoric acid	35	
Calcar. earth	65	
	100	Richter, 1785
Calcar. earth	67.75	
Fluoric acid	32.25	
	100	Klaproth, 1807.

With regard to the *geognoftic fituation* of fluor fpar much is left to future obfervation. We know, however, that it does not only occur in veins, but likewife as beds, principally in mountains of older formation. In Derbyfhire it appears to form large irregular depofitions in fletz lime-ftone, and alfo in Thuringia and at Zinnwald in Bohemia it occurs in beds. More frequently it is met with in veins of different relative ages, accompanied with feveral important metallic formations. The oldeft, confifting principally of tin ftone, occurs at Zinnwald, and in other parts of the Bohemian and Saxon Ertzgebirge: and a vein formation, equally old, is found in Switzerland, where the veins confift of fluor fpar, feldfpar, rock cryftal, &c. The fecond in antiquity appears to be that which, accompanied with lead and filver ores, and fometimes with barytes, forms the fubftance of veins at Freiberg and other parts of the Saxon Erzgebirge, and alfo partly in Derbyfhire. A third vein formation, found in the lower parts of the Hartz, confifts chiefly of fluor fpar with copper and iron pyrites, galena, fpathofe iron, &c. The different ages of the venigenous fluor fpar have firft been examined into by Werner. We fhould alfo mention here that the variety of fluor called chlorophane is found in a granitic rock in Siberia; and Andrada fpeaks of a variety he faw in Sweden (in the diftrict of Norberg) mixed in large maffes with mica flate.

A lift of localities of fluor fpar may be found in all books on mineralogy; indeed, it is met with in moft parts of Europe, though in fome it is found in no confiderable quantity. England and Saxony are the principal native places of this interefting mineral fubftance. In Scotland it is very fcarce; the only localities known to Mr. Jamefon are Aberdeenfhire and the Shetland iflands. We know of no fpecimens from any part of America or Africa; in the northern parts of Afia, Patrin found it in fmall quantities in two mines, *viz.* in the filver mine of Zmeof, in the Altaic mountains, where it occurs mixed with the other vein-materials; and in a lead mine in Dauria, near the river Amur, where, if Patrin's obfervation be correct, it coats the fmall cavities of the vein ftone, in the fhape of a thick *botroidal* cruft.

The ufes to which fluor fpar is applied, though not manifold, are not unimportant. The coarfer kinds are ufed as fluxes to metallic ores, particularly copper, iron, and filver. Chemifts obtain fluoric acid from it. The ufe made of it in this country, (particularly of the variety called blue jack by the Derbyfhire miners,) for ornamental vafes, columns, &c. is generally known. Mr. Mawe, in his "Mineralogy of Derbyfhire," has given an account of the mode of working it. Several attempts have been made in France to manufacture the fluor fpar of Auvergne into fimilar articles of ornament; but it appears as if the nature of its fracture renders it lefs fit for the lathe.

Fluor fpar is feldom feen to conftitute the fubftance of organic remains. We find inftances of this converfion mentioned in Mr. Martin's "Outlines:" the remains are chiefly thofe of entrochitæ. Alfo Dr. Kidd, in his "Outlines, &c." defcribes a bivalve fhell in the Oxford collection, converted into fluor fpar with imperfect cryftals of nearly colourlefs fluor in the interior.

We fhould not omit mentioning in this place thofe corroded cubic cryftals of fluor fpar, of a yellowifh-grey colour, found near the furface of the earth in fome parts of Derbyfhire: their texture is more or lefs porous throughout. Haüy, who calls this variety chaux fluatée aluminifère, thinks that the ferruginous clay which it is faid to contain has the fame relation to the fluor fpar which the quartz grains have to the carbonate of lime in the cryftallized fandftone of Fontainebleau. But this analogy does not appear to be founded in reality. (See Sandstone.) Dr. Kidd conjectures that the corroded appearance of thefe cryftals may have been produced by fome form of zinc.

Fluor fpar fometimes exhibits traces of decompofition. The fingular variety from Beeralfton, Devonfhire, in octaedral cryftals of a pale feladon green colour, and cafed, as it were, in one another, is encrufted with a white earthy fubftance, which, if we may judge from the gradual

transition into the perfect substance observable in a specimen before us, can only be the result of a disintegration of the constituent parts. Mr. Sowerby has given a good figure of this variety. It is probable that much of the substance described as earthy fluor is nothing but fluor in a decomposed state.

FLUOR *Albus*, in *Medicine*, a colourless discharge from the female vagina, popularly termed *the whites*, and by the nosologists *leucorrhœa*, an appellation of the same signification, derived from the Greek. See LEUCORRHŒA.

FLUORIC ACID, in *Chemistry*. This acid was discovered by Scheele more than thirty years ago, and the subject soon after excited the diligent attention of Dr. Priestley, whose experiments and observations are detailed at large in the second volume of his experiments methodized, p. 339, 367. For many years it was supposed to exist in the fluor spar only, but later processes have shewn that it is a constituent of some of the topazes, and of the wavellite, a newly discovered fossil. It has also been found in the animal kingdom, *viz.* in the enamel of the petrified teeth of an elephant: also in the enamel of the human teeth, and in ivory.

We have seen that the constituent parts of fluor spar, independently of the water in combination, are fluoric acid and lime. To obtain this acid we must put one part by weight of the spar coarsely pulverized into a leaden retort, and pour over it three parts of concentrated sulphuric acid. An effervescence is immediately excited; the sulphuric acid exerting a stronger attraction for the lime of the spar, unites with it, and the fluoric acid goes off in the form of gas, which may be collected in receivers over mercury. If water had been previously introduced into the receiver, the gas would have been absorbed, and the acid would, in that case, be exhibited in the liquid state. Hence fluoric acid can subsist in the liquid form, and likewise under that of gas, which gas has the common properties of the atmospheric air, being elastic and invisible. But it is somewhat heavier than common air; it extinguishes combustion, and is utterly incapable of supporting animal life. Exposed to the atmosphere it combines very greedily with its moisture, and appears in the form of vapour or white fumes. It has a penetrating pungent smell; reddens vegetable blues, and corrodes the skin. If a lighted candle be introduced into it, the flame becomes green, and then is extinguished. The most remarkable property of the fluoric acid gas is that of corroding glass in consequence of its strong affinity for silex. This property has rendered it extremely useful in etching or engraving on glass vessels, which operation is performed by a very simple and easy process: the glass is covered with wax, or a strong solution of isinglass, the figures are then traced with a common graver, or steel point, and then the vessel is exposed to the action of the fluoric acid in a state of gas; those parts that are exposed are soon corroded, and the impression is more or less deep, according to the time employed. This art, though adopted as new at the time of Scheele's and Priestley's discoveries, was, according to the account given by Beckmann in the second volume of his History of Inventions, known and practised a century before.

Light and caloric have no effect on fluoric acid; its properties are not the least altered by being passed through a red-hot porcelain tube. It will not unite with oxygen, which is the great difference that exists between this and the muriatic acid; nor has it any action on azote, hydrogen, carbon, phosphorus, or sulphur. By these, or by some of them, almost all the other acids have been decomposed, and their constituents detected, and hence its base was, till very lately, wholly unknown; and it was, from analogy only, that chemists assumed that it must contain oxygen in combination with an unknown base. Mr. Davy has, however, thrown some light on this subject, by subjecting the fluoric acid-gas to the action of potassium, one of his newly discovered metals. In this gas potassium, when heated, burns, and there is a great absorption of the gas. Either the whole, or part of the acid, according to the quantity of the potassium used, is destroyed or absorbed, and the residual elastic fluid is found to be hydrogen, which is in less proportion as the fluoric acid gas has been more perfectly freed from water. After the combustion, a chocolate coloured mass remains at the bottom of the retort, and also a sublimate, partly chocolate coloured, and partly yellow, is found about the sides, and at the top of the retort. This substance, when examined by a magnifier, appeared to consist of different kinds of matter; and when thrown into water it effervesced very violently, and the gas evolved was inflammable. When heated in contact with air it burnt slowly, lost its brown colour, and became a white saline substance.

The water which had acted on this substance was examined, the solid particles separated by a filtre, and the fluid was found to contain fluate of pot-ash, and pot-ash. The solid residuum was heated in oxygen gas, it burnt before it came to a red heat, the brown colour was changed to white; oxygen was absorbed, and acid matter was produced. The inflammable substance thus produced from the action of potassium on the fluoric acid is supposed to be the base of the acid. Perhaps the decomposition of the fluoric acid by potassium is analogous to that of the sulphuric and phosphoric acids; in which the pure bases are not evolved, nor even the bases in their common form, but new compounds formed of the base with potassium, with a smaller proportion of oxygen. This subject has engaged also the attention of the French chemists, M. M. Gay Lussac and Thenard, who employed the agency of potassium, and the results of their investigation were very similar to those of Mr. Davy. From which they infer that since little or no hydrogen gas is evolved in the combustion of potassium, the effect cannot be ascribed to the agency of water. The acid must therefore be decomposed, or it must combine undecomposed with the metallic base, which is not even oxydated. It is probable, therefore, that the acid is decomposed, and the product is a combination of the fluoric base with pot-ash, analogous in constitution to a phosphuret.

Fluoric acid combines with alkalies and earths, and the salts so formed are named fluates. They are generally deliquescent, and can be crystallized with difficulty. They are decomposed by the sulphuric or muriatic acid, which, as we have seen, disengages the fluoric. The alkaline fluates are decomposed also by lime, as is evident by the following

Table of Affinities.

Lime,
Barytes,
Strontites,
Magnesia,
Pot-ash,
Soda,
Ammonia,
Glucina,
Alumine,
Zircon,
Silica.

The saturating power of this acid exceeds that of all the

others, a given quantity of it saturating a larger quantity of any base. On this account, it is regarded as the most powerful of the acids, and its less energetic action must be ascribed partly to the weak state of concentration in which it can be obtained, and partly to its not affording oxygen in a direct way.

There are eight fluates known, *viz.* of pot-ash, soda, ammonia, lime, barytes, magnesia, alumine, and silica. Some of these we shall briefly notice. The fluate of *pot-ash* is obtained by fusing, in a platina crucible, a mixture of fluor spar, and carbonate of pot-ash. The mass, digested in water, yields a solution, which, filtered and evaporated, leaves a fluate of pot-ash. It does not crystallize, but forms a gelatinous mass with scarcely any taste, that attracts moisture from the air. It readily dissolves in water. F. of *soda* is formed like the last; if the solution is evaporated till a pellicle rises on its surface, it yields on cooling small cubical crystals of fluate of soda. These are bitter and astringent; they do not deliquesce in the air, and are but little soluble in water. They decrepitate and melt into a transparent globule when exposed to the action of the blow-pipe. F. of ammonia is obtained by the application of heat to a mixture of sulphate of ammonia and fluor spar. The fluate sublimes; but if it is prepared by saturating the acid with ammonia, the solution, by evaporation, yields small crystals of fluate of ammonia. F. of lime, is the fluor spar on which we have already treated, as it is found in nature; this salt may be artificially prepared by adding fluate of ammonia to nitrate of lime; the fluate of lime falls to the bottom, and when properly treated is very pure. It is insoluble in water, phosphorescent when laid on a hot iron, it is insipid, unalterable by exposure to the air, and at a heat equal to 51° of Wedgwood, it melts into a colourless transparent glass. Fluoric acid obtained in glass vessels always contains a portion of silica; if this solution be allowed to remain a considerable time in a vessel not quite closed, it deposits small brilliant transparent crystals, which have been ascertained to be the fluate of silica. This salt is soluble in alkalies, and gives out fluoric acid by mere heat, or by the action of any of the strong mineral acids. Felspar, and all minerals that contain silica, are probably acted on without difficulty by the fluoric acid in a state of gas, but those that contain no alkali are less liable to its action. The following table, taken from Dr. Thomson's chemistry, vol. ii. exhibits the results of the experiments and calculations of Richter on the several fluates.

Table of the Composition of the Fluates.

Fluates of	Acid.	Base.
Alumine - -	100 - -	123
Magnesia -	100 -	144
Ammonia -	100 - -	157
Lime - -	100 -	186
Soda - -	100 - -	201
Strontian - -	100 -	311
Pot-ash -	100 - -	376
Barytes - -	100 -	520

Flux

FLUX, in *Enamel*, is that glaſſy body that forms the baſis of all enamels, whether tranſparent, ſemi-tranſparent, or opaque. Now as the painting on enamel is performed with vitreous colours, which to ſpeak truly can be nothing more or leſs than coloured enamels, it muſt be evident that flux likewiſe forms a principal part in the compoſition of enamel colours.

Flux, *Enameller's*, is a ſort of enamel principally uſed for the upper ſurfaces of plates intended for enamel painting. It differs from the common enamels, in being of a more mellow and rich quality, whilſt its properties facilitate the fuſion of thoſe colours which are employed in painting on it. The beſt kinds having been generally brought from Venice, have acquired the name of *Venetian* flux, and are commonly imported in the form of ſmall beads, hence called *bead*-flux, or ſhort pipes about three-eighths of an inch in diameter, and from three quarters of an inch to an inch in length: the latter is called *pipe*-flux. The fluxed plates, when prepared as deſcribed under Enamelling, have a rich yellow hue, or cream colour; by which they are rendered of particular utility in paintings where much of the naked figure is expoſed. The flux muſt always be laid upon *hard* enamel; as the properties of glaſs enamel are inimical to effective coheſion, the flux cracking in circles, or flying off in pieces as the plates cool.

In order to give a clear idea of the nature of fluxes, it will not be improper previouſly to inquire more particularly into the nature of the ingredients, their operations on each other in a ſtate of compoſition, as well as the power which each exerts in producing a proper effect; ſince by this means ſuch an initiative knowledge may be obtained, as will enable perſons unacquainted with the art to conduct their experiments with more certainty, than they poſſibly could by any particular recipes, however good they might be.

There are two kinds of ſubſtances which enter into the compoſition of enamel fluxes; the one, the proper matter of the flux, being principally ſuch bodies as are by their nature endued with a ſtrong propenſity to run into the vitreous fuſion, and be converted into glaſs, at the ſame time that they aſſimilate and change other bodies in combination with them into their own vitreous nature. This kind conſiſts principally of ſalts, lead, and arſenic. The other kind conſiſts of the correctives of theſe proper fluxings, which without their admixture would be found to have qualities that would deprave them for enamels or the fluxes for paintings. For all kinds of ſalts, when vitrified by themſelves, or with a ſmall proportion of other bodies, are ſtill liable to be diſſolved by aqueous moiſture; and flux, made of ſuch ingredients only, would be corroded even by the common air, and turn black and dull on its ſurface; hence it becomes neceſſary to add ſome other bodies as correctives to prevent theſe bad tendencies, and render the flux more durable. Lead and arſenic, when formed into glaſs, of which they compoſe the principal ingredients, are particularly liable to be thus corroded; to prevent which, when uſing theſe ſubſtances, it is neceſſary to add conſiderable proportions of the corrective matter. The truth of theſe remarks may be readily aſcertained by the appearance of the enamel door-plates about this town, in many of which the lead, having been uſed in too great a proportion as a flux for the black colour, has been ſo far corroded as to have admitted the air to come in contact with the colouring matter, in which caſe the whole writing is almoſt obliterated.

The moſt common of theſe corrective bodies of the proper matter of the flux, and which therefore make the ſecond kind of ſubſtances of which enamel fluxes are compoſed, are calcined flints, and Lynn ſand, or what is generally known by the name of ſilver ſand, which being perfectly white, and reſiſting when vitrified the corroſive and

decomposing action of all menstrua, give body and hardness to the fluxes, without any other disadvantage than that of diminishing, in a certain degree, their inclination to vitrify, and on that account rendering them somewhat weaker as fluxes than they would be if used alone.

The most active kind of salt as a general flux is borax, which possesses the greatest power of any simple body hitherto known. Lead, which is the next, vitrifies with a very slight heat, and at the same time assimilates other bodies to its own nature, such as earths, stones, the oxyds of metals, &c. Arsenic is likewise a powerful fluxing substance; but whenever this is used it should be with bodies that have been previously vitrified and ground tolerably fine, otherwise it is apt to sublime and fly off from the composition with which it is mixed, and which of course must render any recipe, where a certain proportion of this is to be used, very liable to error without such precautions. Several kinds of salts possess the next degree of fluxing power, the principal of which is sea salt; but it must be evident from what has been mentioned, that they are not sufficiently strong to form an enamel flux by themselves, yet as they are perfectly colourless when vitrified, which is not the case with lead, they will be found very useful in composition with lead, or when used in place of that substance, assisted by borax, especially where any tinge of yellow would be detrimental to the colouring matter that is to be used with the flux.

Having endeavoured to give the reader an idea of the nature of the substances that are used in the formation of fluxes, we shall next endeavour to explain the method of compounding them before they are fused, and also some observations upon that part of the process.

When the materials are procured, taking care that they are of the best quality, each should be separately levigated either in an agate mortar, or one made of the same kind of glass as the common wine bottles are made of: the pestle in either case should be of flint or agate. The proportions of each substance, having first been thoroughly mixed, the whole must be put into crucibles of a proper size, and placed in an air furnace, or what is more commonly called a wind hole, where the heat should be increased till the matter is perfectly vitrified, which may be known by its becoming clear and transparent. The heat must be sufficiently powerful, yet not too violent, for though a great heat may accelerate the vitrification, yet it at all times hardens the composition, and greatly reduces the fluxing power. The simple method of dipping the end of a tobacco pipe in the flux while in a state of fusion, and examining the small quantity that adheres to it, will enable a person to form an accurate judgment of the whole; for if it appears clear and transparent it may be concluded that the vitrification is complete, but if any cloudy parts appear inclosing opaque specks, it is evident that a longer continuation of heat is necessary. When the quantity is small it becomes very difficult to get the whole out of the pot; the best method perhaps is to hold the edge of the pot with a convenient pair of tongs, and at the same time scrape the matter out with a small piece of iron, the edge of which should be previously made to fit the bottom of the crucible. Whoever would have flux in the greatest degree of purity, must previously prepare the glass of lead to be ready at all times for use, for although lead might be mixed with the other ingredients for common purposes, yet it will be better in all cases to prepare it previously by the following means.

Take of the best minium, or, as it is commonly called, red lead, four pounds; of Lynn sand, or calcined flints, two pounds and a quarter: these two substances should be thoroughly mixed, and be put into a very sound crucible. One that has had flux or a little flint glass melted in it before would be preferable, for when a new pot is used, the lead is very liable to strain through the pores, and thus occasion an uncertain result, although the quantities should have been ever so nicely adjusted. This is to be vitrified in the same manner as directed for flux, and when perfect will be of a beautiful topaz or transparent gold colour. When the matter is cold, it should be ground in the mortar before described, and then kept perfectly free from dust.

In most large concerns in the glass business sand is greatly preferable to flints, as the trouble of calcining and grinding the latter, where large quantities are wanted, is a serious objection to their use. But in the case of flux, where quality is of more consequence than quantity, flints are certainly preferable.

The method of preparing the flints for use, is to place them in a clear fire, in which they should continue two or three hours; the fire should be then increased till they attain a white heat, at which time they should be taken very quickly from the fire and plunged into cold water, which will cause them to crack and flaw in innumerable parts; they must then be broken into pieces, and if they are of an uniform whiteness throughout, they may be considered as fit for grinding; but if any black and discoloured places appear, they must be again submitted to the fire, and the immersion in water repeated; the calcination being then completed, they must be broken as small as possible with a steel-faced hammer, and ground very fine in the glass or agate mortar.

A very important advantage attending this preparation of the glass of lead, is the ease with which a very perfect vitrification of the sand or flints is effected without the aid of intense heat; at the same time the mixture is rendered more capable of assimilating with a larger proportion of salts, which will in all cases add greatly to the softness of the flux.

Very little hope is entertained that any more of the Venetian hard enamel or flux for grounds will be imported into this country, as we are assured that Bertolini, the celebrated maker of those substances, perished in the hands of the French at Naples, on account of his political opinions. We feel much pleasure in being able to state, however, that Mr. Griffiths of Broad Court, Long Acre, London, after many years spent in making enamel colours, has succeeded in making flux for grounds equal to any of the Venetian, which he has constantly for sale. He has likewise, within the last three years, brought to perfection a beautiful white, hard enamel, which is so nearly equal to the Venetian, that the one might be mistaken for the other, the colour and fracture being so much alike.

The first recipe for the formation of a flux, and which we shall call No 1, is the white glass enamel, which, containing a large proportion of arsenic in a semi-vitrified state, requires to be broken into small pieces, and fused till the matter becomes quite clear and transparent; the arsenic will by this means be completely vitrified, and convert the glass into a soft and useful flux, fit to be mixed with most of the earths that may be used as colours, and likewise with the oxyds of all the metals, gold and silver excepted; for it must be remembered, that lead and arsenic are both apt to injure the beauty of the colours that are produced by gold and silver: therefore, whenever these are used, it must be with a flux that is composed without either of these ingredients; or if they do enter the composition, it must be in very small proportions.

Composition of a softer flux for common purposes, where

the glafs may be found too hard, N° 2.—Take of the glafs of lead one pound; of pearl afhes, five ounces; of borax, five ounces; and of arfenic, half an ounce. This flux is fuited, by its foftnefs, to be mixed with colours that are to be ufed in glazing over others, where a harder flux has been ufed, and in moft cafes, where burning the colours with a flight heat is advantageous.

Compofition of a flux perfectly pellucid and very foft, N° 3.—Take of common flint glafs, powdered very fine, feven ounces; of borax, one ounce and a half; of pearl afhes, two ounces; and of fea-falt, one ounce. This flux, by its foftnefs and clearnefs, will be found very ufeful for the oxyds of gold and filver; likewife in all cafes where a tinge in the flux might be detrimental to the colouring fubftance that is to be ufed.

Thefe fluxes, in the proportion here given, have been found to anfwer the purpofes for which they are intended extremely well; but as the ingredients fometimes vary in their quality, it is evident that much muft at all times be left for the ingenuity of the operator to fupply. Indeed, when the difficulties that every perfon muft meet with in attempts of this nature, without a previous knowledge of chemiftry, are confidered, we cannot do better than advife a ftudy of that fcience as an introduction to the art of enamelling and enamel painting, by which means a complete theory of the various fubftances may be obtained, which, in the courfe of practice, may lead to ufeful difcoveries; or, to fay the leaft, will many times prevent ufelefs experiments being made.

We muft not omit noticing in this place, that dial-plate enamellers found great inconvenience in the lofs of the Venetian white hard enamel, as that fubftance was principally ufed for the bottoms or backs of dial-plates manufactured of the Englifh glafs enamel; for the expanfion of thefe two fubftances fo exactly fuited each other, that it was very rare that any of them cracked in the fire. This, however, was not the cafe with all the kinds that were brought from Venice, and particularly a blue fort, ftamped on the cakes with the figure of a monkey, and commonly called monkey-enamel. This fort was very apt to crack the plates in circles, after they had been made a few weeks, unlefs it was ufed in compofition with other fubftances, whofe fluxes, being fofter, contributed to counteract this difagreeable property.

Thefe obfervations tend to confirm what we have before ftated refpecting the neceffity of laying flux for grounds on hard enamel, becaufe the Englifh glafs enamel, being much harder from the nature of its compofition, does not run into fufion with the fame heat as the flux; confequently a perfect adhefion cannot take place between thefe two fubftances. For a further account of the proportions of flux ufed in enamel colours, fee Painting *on Enamel*. Handmaid to the Arts, vol. i. and ii.

Flux, in *Hydrography*, a regular, periodical motion of the fea, happening twice in twenty-four hours; wherein the water is raifed, and driven violently againft the fhores.

The flux, or flow, is one of the motions of the tide, (fee Tide): the other, whereby the water finks and retires, is called the reflux, or ebb.

There is alfo a kind of reft, or ceffation of about half an hour, between the flux and reflux; during which time the water is at its greateft height, called *high-water*.

The flux is made by the motion of the water of the fea, from the equator towards the poles; which, in its progrefs, ftriking againft the coafts in its way, and meeting with oppofition from them, fwells, and where it can find paffage, as in flats, rivers, &c. rifes up, and runs into the land.

This motion follows, in fome meafure, the courfe of the moon; as it lofes or comes later every day by about three quarters of an hour; or, more precifely, by forty-eight minutes: and by fo much is the motion of the moon flower than that of the fun. It is always higheft and greateft in full moons, particularly thofe of the equinoxes. In fome parts, as at mount St. Michael, it rifes eighty or ninety feet, though in the open fea it never rifes above a foot or two; and in fome places, as about the Morea, there is no flux at all. It runs up fome rivers above a hundred and twenty miles. Up the river Thames it only goes eighty, *viz.* near to Kingfton in Surry.

Above London-bridge, the water flows four hours, and ebbs eight; and below the bridge, flows five hours, and ebbs feven. See Tides.

Flux, in *Medicine*, often called alfo *bloody flux*, the popular appellation of *Dyfentery*, which fee.

Flux, in *Metallurgy*. All thofe fubftances which have been employed to facilitate the feparation of metals from their ores, or to give greater fluidity in the fufing or foldering of metals, have by manufacturers been denominated fluxes.

Fluxes employed in feparating metals from their ores have the effect of rendering the fubftances with which the metal is combined, capable of fufion. The whole is, by this addition of the flux, rendered fluid; the metal, being the heavieft fluid, finks to the bottom; while the fluid mafs, arifing from the earthy matters of the ore, combined with the flux, floats on the furface: the latter, on cooling, puts on a vitreous appearance, and is, by manufacturers, called *fcoria*. Hence it will appear, that the flux employed muft be fuch a fubftance as may be beft calculated to render thofe fubftances more fufible with which the metal is combined.

If the ore abounds with filex, potafh or foda is beft calculated to feparate it from the metal. Tartar, which confifts of the tartaric acid united with the potafh, and frequently abounds with much vegetable matter, is employed to great advantage in the fmall way. The hydrogen and carbon prefent, take the oxygen from the metal; while the potafh combines with the filex, forming a fluid vitreous mafs, more or lefs coloured by the oxyd of the metal.

The fubftances known by the names of black flux and white flux are generally ufed in the fmaller experiments. The former is made by detonating one part of nitre with three of tartar, fo that it contains at leaft an excefs of carbonaceous matter, which is fitted for the reduction of the metallic oxyd, while the potafh, derived from the nitre and tartar, combines with the earthy products.

That called white flux, is formed by detonating equal parts of nitre and tartar, by projecting the mixture, by a fmall quantity at a time, into a red-hot crucible. In thefe proportions the whole of the carbonaceous matter of the tartar is deftroyed by the oxygen of the nitre, and nothing more is obtained than a fub-carbonat of potafh.

It will appear evident to every chemift, that common tartar, or for nice experiments, that fuper-tartaret of potafh, will anfwer all the purpofe of the black flux, and the fub-carbonat of potafh be equally well taken for the latter. Some have recommended the nitre and tartar to be ufed together; but this will always be improper where the oxydation of a fubftance is intended. Nitre poffeffes a power fo much the contrary, that it is capable of oxydating gold.

In the large way, on account of cheapnefs, lime is employed to feparate the filex. Barytes, if it could be found more plentifully, might be ufed to more advantage for feparating filex, particularly from iron ore.

Lime is found to be the beft flux for fmelting the alumi-

nous iron ores, from the great fusibility of due proportions of those two earths. Should the ore abound with silex, its reduction is found more difficult. It might be an advantage, where ores of this kind occur, to use some cheap compound of barytes, such as the sulphat of that earth.

From what has been observed, it will appear that it is of the greatest importance to be acquainted with the nature of the earthy matter in the different ores. Whether the ore contain alumine, lime, or both these substances, such a quantity of one of them should be added, as will make the most fusible compound of the two. If the alumine be in excess, lime must be added, but if the ore be calcareous, which is sometimes the case, it is found necessary to add clay. In the smelting of iron ores, however, the fusibility of the earths is much increased by the oxyd of iron, which always, more or less, colours the scoria. The oxyd of iron is found to exert a much stronger affinity upon silex than upon any of the other earths, and hence those iron ores abounding with silex, when smelted, afford more coloured scoria, and in consequence are less productive.

In the smelting of copper ores, which contain silex, it is common to add some substance which contains oxyd of iron; pyrites is generally used to afford this substance. But many copper ores contain iron, and need not the addition of this substance as a flux. The oxyd of iron combines with the silex, forming a dark coloured fusible compound, which floats on the surface, leaving the copper free from both those substances.

Most of the fluxes used in fusing or soldering those metals liable to oxydate by the presence of the oxygen of the atmosphere are such, as by fusing, when the metal would begin to oxydate, envelope the metallic surface, and prevent the combination of the oxygen. Of this class are many saline bodies, such as borax, pot-ash, soda, tartar, muriat of soda, &c. In short it should be such a substance as may fuse before the body becomes very hot. It should have no action upon the metal itself, and it should possess so much fixity as not to be volatilized by the heat required for the fusion of the metal. If the flux be at all liable to fly off, a fresh quantity should be frequently added.

Another species of fluxes act by reducing the oxyd as fast as it may be formed. The fusible metals are generally treated with those inflammable bodies, which combine with oxygen, with great facility, and at the same time involve the metallic surface. Rosin and fatty substances are mostly employed for lead, tin, antimony, and bismuth, or their alloys. Zinc requires to be treated in a close vessel with charcoal powder, or pounded pit-coal.

The vitreous and saline fluxes which act by preventing oxydation, are employed for cast iron, copper, brass, &c.

Pounded glass, or a mixture of lime and clay, may be employed for cast iron; pot-ash or tartar for copper and brass.

The scoria of blast furnaces is generally used in the fusion of steel which is to be cast into ingots. If too much of these fluxes be used, the firmness of the crucible will be endangered. Muriat of ammonia has a very peculiar property of freeing the surfaces of metals from oxygen. This has been explained, by supposing that the ammonia is decomposed; the hydrogen of which combines with the oxygen. This does not, however, clearly explain the fact, for the muriat of ammonia is not decomposed by this process, and much less by the ammonia. It is well known to those who manufacture this muriat, that if any metallic oxyd be present when this salt is sublimed, the oxyd rises with it, forming a triple salt. Indeed the substance, known in medicine by the name of *floria martialis*, is formed in this way, and is a triple muriat of iron and ammonia.

The great utility of this salt in the soldering of metals, therefore, consists in carrying off the oxyd from the surface, at the time it sublimes.

Rosin and fat substances used in solderings give great fluidity and brightness to the solder, and clear the surfaces to be united, by their carbon and hydrogen taking the oxygen which may be present.

The flux employed for soldering iron, brass, and copper, are generally borax, (sub-borat of soda.) After the solder and the surfaces are once made clean, this borax acts, by preventing oxydation, till the solder fuses, and unites the two surfaces.

That this is the true explanation of the action of a flux, in soldering, we have abundant proof, in soldering one noble metal with another. When fine gold is employed for soldering platina, the gold is observed at the time of fusion to assume a degree of fluidity far superior to any solder made of oxydable metals, although the latter be assisted with the best flux.

In the fusion of those metals liable to oxydate, whether the fusion may be for the purpose of soldering or casting, certain fluxes are found to be indispensable. The fluidity is so much improved, that in the latter process, without a flux, the solder would not be able to run between the surfaces to be united, independent of its action in preventing the oxydation of the surfaces. In the casting of metals, the fluidity would sometimes be so imperfect, without the presence of the flux, that impressions taken from the mould would be exceedingly defective, and small articles, such as needles and fish hooks, could not be cast at all.

We shall conclude this article by giving a short explanation of the cause of increase of fluidity by the agency of fluxes.

Although an idea is entertained by chemists, that there is no medium between that pulverulent state called the oxydated and the metallic states, it will be found that the oxydable metals combine with oxygen when exposed to the air in a state of fusion, without losing their metallic form. They however lose much of their lustre and fluidity. Of this fact we have a striking proof in silver, which in the act of refining has been long exposed to a current of oxygen for the purpose of freeing it from the baser metals. At the time the silver assumes the solid form, the oxygen is given out in the form of gas. Mr. Lucas, a refiner of Sheffield, by throwing the liquid silver into water, collected an abundance of pure oxygen gas.

The partial loss of lustre and fluidity from the combined oxygen, is soon very apparent in melted zinc, both of which may be completely restored, by treating it in a close vessel with charcoal powder. All the oxydable metals are more or less susceptible of this change, proportionate to their affinity for that substance.

From what has been observed we may infer, that it is highly injudicious to expose much of the melted surface of metals to the air. Hence the iron ladles used for the fusible metals, as well as crucibles, ought to be as narrow as possible at the top, at the same time that some substance should be employed, which will either prevent the oxydation, or reduce the oxyd as it is formed.

Fluxes, in the *Manufacture of Glass*, are red-lead, pearl-ashes, nitre, sea-salt, borax, arsenic, the scoria of forges, commonly called clinkers, and wood-ashes. See Glass.

Fly

FLY, in *Mechanics*, is an apparatus employed to equalize and regulate the velocity and power of many machines which require such regulation from the inequality either of the moving power, or of the resistance it has to overcome. A fly acts upon the principle that any body, being put in motion with a certain velocity at a certain expence of power, will continue to move until its motion is stopped by a resistance equal to its momentum or sum of the power and velocity which first caused its motion. This principle is carried into effect by various forms of the apparatus; the mass being generally made to revolve upon a centre, and the parts on the opposite sides of the centre being balanced. Two, four, or any other number of equal weights, placed on the opposite ends of arms or radii which are affixed to an axis, constitute a fly. If the weights be supposed to touch each other, or a hoop or ring of one piece be substituted, its form will be much improved; and it is now termed a fly-wheel, and is the manner in which the fly is most generally used.

The friction or resistance which the air opposes to any body in motion, and the friction of the pivots which support the axis of a fly-wheel, are considerable deductions from the power communicated to it; so that instead of a fly-wheel gaining power, as some imagine, it requires a constant exertion of power to keep it in motion, even when no other resistance is applied to prevent it. For this reason a mechanic should never introduce a fly-wheel into a machine, unless the advantages to be derived from its action are greater than the actual loss of power it occasions. As an instance, we will suppose a heavy stamper or hammer to be raised by a water-wheel; the action of the water upon the wheel is constant and uniform, and whilst the machine is lifting the hammer, this action is nearly balanced; but the instant the hammer falls, the principal resistance or load to the water-wheel is removed, and the water urges it rapidly forwards, until it meets the hammer again, when it is suddenly checked, and moves with diminished velocity, until it again loses its load. In such a case as this the fly-wheel is of great service, for in the interval while the resistance to the water-wheel is not in action, it prevents its acceleration, the power of the water-wheel being employed to give a momentum to the fly-wheel; and as soon as the velocity of the water-wheel is at all diminished, by the return of its load, the momentum of the fly acts to carry it forwards, and continue the motion with the same velocity until the momentum is expended in assisting the water-wheel. By this time the hammer has fallen, and the water-wheel left at liberty to communicate a new impulse to the fly.

In this, and many other similar cases, the power expended in giving motion to the fly is trifling, compared with what it preserves from complete loss during the interval in which the resistance of the water-wheel is inactive. If the water-wheel had been applied to raising a stamper, the equalization might have been made by using three or four stampers in place of one, and adapting the machine to raise them successively: by this means, the load being divided and applied continually, the motion would be rendered nearly as uniform as by a fly-wheel, and without its inconveniences.

In this manner in many machines where fly-wheels are introduced, they are not absolutely necessary, saw mills, pump mills, &c., where a single machine which only acts in one direction is to be moved, all these might be improved by dividing the load, and causing its parts to act in succession; and for pump mills the double acting pumps may be used to great advantage, in lieu of a single one with a fly-wheel.

It is a great object in constructing flies to form them so as to present the smallest resistance to the air. For this purpose a wheel should always be used; the ring should be smooth and truly circular without any projecting nuts, &c.; the radii should be made to present a thin edge to the air, and the whole should be made of metal, that the greatest weight may be contained under the smallest surface; and for this purpose, if the section of the ring is a circle, the smallest surface will be exposed to form a resistance to the air, the radii should be of an elliptic figure, the narrowest edge meeting the air. This form of a fly-wheel is used by Messrs. Murray and Wood of Leeds in the steam engines which they erect, and is included in a patent they have for steam engines, and though they may have been the first who applied it to steam engines, the idea is not original, as Mr. Sully gave that form to his watch-balances many years ago.

A fly-wheel should be cast in one piece of metal, if it is not too weighty; in which case, the pieces of which it is composed should be melted together in the most solid manner imaginable, lest the centrifugal force of such a large mass, moving with a considerable velocity, should endanger the separation of its pieces. If by any accident the bolts connecting them become loose, or are weakened by rusting, (this failure, which has some times happened, is truly dreadful,) the force with which a fragment of the wheel is projected is irresistible; and if it should chance to strike the walls of the building, it would be in danger of total destruction. A method has been lately introduced of putting fly-wheels together, by dove-tailing instead of screw-bolts. The arms are fastened into the ring, and the segments of the ring fastened together by a system of dove-tails, which only admit of being put together in one direction, which is contrary to that in which the centrifugal force acts. Precaution on this head will not appear useless, when it is considered that fly-wheels of 8 and 10 tons in weight in the ring and arms are common in the machinery used for the manufacturing of iron, and their circumference moving at the rate of 300 feet per minute. We have seen one applied to a steam engine of 16 tons in weight, and moving much quicker. The ring is usually in six pieces, of

about a ton each, and connected only by a few wrought iron bolts as it revolves. The weight of these pieces, constantly acting in new directions, independent of the centrifugal force, is a severe strain upon the bolts and parts forming the connection.

The mode of calculating the size, weight, and velocity of a fly-wheel, proper to regulate the motion of any given piece of machinery, must be very intricate; though it is not usual for practical mechanics to employ calculation, their fly-wheels being adopted from the proportion of some other similar machine, which is found to answer its purpose. This subject has not been investigated in the elementary works on mechanics that we have seen; though, from its great practical utility, it would well repay the labour of any competent analyst, who would turn his thoughts to the subject.

The fly-wheel only acts when the velocity of the machine is variable: for having naturally a tendency to preserve an uniform velocity in itself, it will tend to move the machine connected with it in the same manner. On this account, it would be absurd to employ a fly-wheel in any machine where the power and resistance are always uniform, or bear the same proportion to each other: hence the motion of any machine, deriving assistance from a fly-wheel, cannot be perfectly regular, as it is only when a change in the velocity of the machine takes place that the fly-wheel has any action, and the power it exerts to continue the motion is greater or less, as the change in velocity of the machine is more sudden or slow.

In rolling mills, where the power which will be required is not to be estimated, and at the same time the resistance to the mill is not in action, a great proportion of the time, a large and heavy fly-wheel is necessary; in this case it acts as a collector of power. If the workman has an extraordinary large piece of metal to be rolled, he suffers the mill to work without obstruction a few revolutions of the water-wheel, that the fly-wheel may acquire such a velocity as will overcome the resistance to be opposed to it, which is perhaps far beyond the power of the mill to accomplish without such aid.

The coining press, or fly-press, is another example of the same sort. The momentum of a fly, put in motion by a continued action of several seconds, is expended in an instantaneous stroke upon a piece of metal, acting with astonishing power. The sledge hammer may be instanced as a similar case. The power given to the hammer in a certain space of time, is exerted in an infinitely short time, and with proportional power.

In all cases where the moving force is variable, a fly-wheel must be added, unless the resistance can be adapted to vary in the same degree. A man, turning a winch by his hand, or a crank by his foot, can exert three times the power in many positions which he can in others, particularly in the latter case: a fly-wheel is, therefore, of essential service, and the rotative motion obtained from the steam engine is wholly dependent on the assistance of the fly-wheel.

The fly may be applied to several sorts of engines, whether moved by men, horses, wind, or water; and is of great use in those parts of an engine which have a quick circular motion, and where the power or resistance acts unequally in the different parts of a revolution. In this case the fly, without adding any new force, becomes a moderator, making the motion of revolution almost every where equal and uniform: thus the engine becomes more easily and conveniently acted upon and moved by the impelling force; and this is the only advantage obtained by the fly. The best form of this appendage to machines is that of a wheel or circle, of a proper size, as this will not only be less resisted by the air, but by being continuous, and the weight every where equally distributed through the perimeter of the wheel, the motion will be more easy, uniform, and regular. In this form, the fly is most aptly applied to the perpendicular drill, which it likewise serves to keep upright by its centrifugal force; as also to a windlass or common winch, where the motion is quick; for in pulling upwards from the lower part, a person can exercise a greater power than in thrusting forward in the upper quarter; when, of course, part of his force would be lost, if it were not accumulated and maintained in the equable motion of the fly. Hence, by this application of force, a man may work all day in drawing up a weight of 40 lbs. whereas 30 lbs. would occasion to him greater labour in a day without the fly.

The force of a fly, when joined with the screw, for stamping the image upon coins, may be calculated thus; suppose its two arms to be each fifteen inches long, measuring from the centre of the weights to the axis of the motion, and the weights to be fifty pounds each, and the diameter of the axis pressing upon the dye to be one inch; if every stroke be made in half a second, and the weights describe an half circumference, which will in this case be of four feet, the velocity will at the instant of the stroke be at the rate of eight feet in a second, and, therefore, the momentum eight hundred; but the arms of the fly being as levers, one brachium of which is fifteen inches long, whilst the other, *viz.* the semi-axis, is but half an inch, we must increase this force thirty times, which will give twenty-four thousand; an immense force, equal to that of a hundred pound weight falling a hundred and twenty feet, or near two seconds in time; or to that of a body of seven hundred and fifty pounds, falling $16\frac{1}{12}$ feet, or one second in time.

Some of these engines for coining crown-pieces have the arms of the flies five times as long, and the weights twice as heavy as those here mentioned, so that the effect is ten times greater. Desaguliers' Exper. Philosoph. vol. i. p. 245. 339.

Besides the utility of fly-wheels, as regulators of machinery, they have been employed for accumulating or collecting power. If motion be communicated to a fly-wheel by means of a small force, and if this force be continued till the wheel has acquired a great velocity, such a quantity of motion will be accumulated in its circumference as to overcome resistances, and produce effects, which could never have been accomplished by the original force. So great is this accumulation of power, that a force equivalent to 20 pounds, applied for the space of 37 seconds to the circumference of a cylinder, 20 feet diameter, which weighs 4713 pounds, would, at the distance of one foot from the centre, give an impulse to a musket-ball equal to that which it receives from a full charge of gun-powder. In the space of six minutes ten seconds, the same effect would be produced, if the cylinder were driven by a man who constantly exerted a force of 20 pounds at a winch one foot long. This has been demonstrated by Mr. Atwood in his "Treatise on Rectilineal and Rotatory Motion." This accumulation of power is exemplified in the Sling; and also in the machine for coining, as already stated. Messrs. Watt and Boulton have employed a new kind of fly, called the "Conical Pendulum," for regulating the admission of steam into the cylinder of the Steam-*engine*, which see.

Notwithstanding the great advantages of fly-wheels, both as regulators of machines, and collectors of power, their

utility wholly depends upon the position which is assigned them, with respect to the impelled and working points of the engine. This position depends altogether on the structure of the machinery. It may be observed, however, in general, that where fly-wheels are employed to regulate machinery, they should be near the impelling power. And, when used to accumulate force in the working point, they should not be far distant from it. In hand-mills for grinding corn, the fly is for the most part very injudiciously fixed on the axis to which the winch is attached. It should always be fastened to the upper mill-stone, so as to revolve with the same rapidity. In the first position, indeed, it must equalize the varying efforts of the power which moves the winch, but when it is attached to the turning mill-stone, it not only does this, but contributes very effectually to the grinding of corn. Ferguson's Mechanics, by Brewster, vol. i.

Fly-*press*, an instrument of most extensive use in many manufactures for stamping or cutting small articles in metal. It consists of a chissel, punch, or cutting-tool, moved by a screw, which is furnished with weights acting as a fly. When these are turned rapidly round, the tool exerts an immense power on any substance subjected to its action. The press is often used without the fly, and is still called, though improperly, a fly-press.

Figs. 1, 2, 3, and 4, of *Plate* XXVII. (*Mechanics*) represent a fly-press with its minor parts, such as is in common use in Sheffield in a variety of manufactures, which we shall enumerate in their proper heads. A AA, *figs.* 1 and 2, is a massive frame of cast-iron, of the dimensions expressed by the drawing and scale annexed. In the upper part of this frame a female screw, or screw-box is fitted, and the screw B passes through it. The top of the screw is fixed to a curved handle *a b c*, furnished with a heavy weight *c*, which acts as a fly, when the handle is turned round by a workman sitting before a bench or table, on which the press is fastened by two bolts passing through projecting pieces, *d*, *d*, of the iron frame. At *e* a piece of iron is fastened, projecting from the iron frame, and supporting a socket for the square iron slider *f* to slide up and down through, and to avoid any shake in its motion. The socket can be at any time made to fit the slider by the four screws (seen in both figures) which draw the two halves of the socket together. The upper end of the slider *f* is connected with the screw B, by a joint which allows the screw to turn round independent of the slider, but obliges the latter to accompany the screw in its vertical motion, either ascending or descending. At the lower end of the slider *f*, the punch or tool, *g*, is fastened by a clamp-screw: it acts in combination with another tool, *h*, called the die, fixed below it in the frame by four screws *i*, as shewn in *fig.* 3, which allow of its adjustment in the true position beneath the tool. The lower tool, or die, *i*, is fitted into a block, which is held by the four screws, and by this means the die can be quickly changed without disturbing the press. The upper tool can be removed in the same manner by releasing the clamp-screw which holds it in the slider *f*.

These, as the essential parts of the fly-press and its operation, are too simple to require much explanation. The workman, being seated before the press, holds the piece of metal to be acted upon in his left-hand, and draws the handle *a* towards him with the other: this, by turning the screws, forces the punch down upon the metal, and the momentum of the weight *c* causes it to act with such force, that the resistance of punching through a thick piece of metal is scarcely perceptible upon the handle. The principal part of this power is gained by the screw as well as by the accumulated *vis inertiæ* of the fly. For many purposes where the resistance is but slight, the weight *c* is removed: the press acts simply by the lever and screw. It still retains, though improperly, the name of the fly-press. This alteration is intended to give the workman such a command of the machine, that he can more quickly reverse the motion than will be the case when the fly is in action. This can be only done where the resistance is very slight. Nails, the teeth of saws, open-work of fenders, and similar articles, are cut with appropriate tools in this manner. *Figs.* 4. and 5. represent some of the tools to be used in the press; *a* is a punch, and *b* the socket, or die, for perforating a circular hole, either with the view of forming a hole in a metallic plate for rivetting, &c. or to preserve the piece struck out for boat-builders rivets, washers, or collets, buttons, ornamental studs for fenders, and a vast variety of other purposes in which small circles of metal are useful. These pieces are forced through the die, and fall through a hole made in the frame A, into a small drawer placed beneath the bench for their reception.

C, D, are another pair of tools, in which the die D is embossed to the shape intended to be impressed on the ornamental studs cut by the former punch. These are forced into it by the flat surface of the upper tool C. In some cases this tool at the same time punches a small hole by which the stud is to be rivetted to the article it is intended to ornament, and the die must then be perforated with a small hole to convey away the fragment of metal forced out by the punch. In many cases these studs are intended to be fastened on by a small pin projecting from their lower surface: in this case they are forged or cast in the manner of a nail, and the point or shank of a stud being inserted into a hole. In the lower die the upper tool is forced down upon it, and imprints its figure upon its head: it is plain that here the upper tool must be embossed instead of the lower. A concave or convex figure is given to the small circles before-mentioned, by making the end of the punch *a*, *fig.* 4. concave or convex, and the pressure it exerts to force out a piece of plate is sufficient to impose upon the fragment the figure of the punch. In *fig.* 5. E, F are another small pair of dies for punching small circular holes, and G H is a similar pair of tools for square holes.

The manner of punching out the concave shells for small buttons, which are termed *shell* buttons, is deserving of notice. First, small circles, (one of which is seen in the section at *r*, *fig.* 6.) are cut out from plate-brass, by a plain round punch and die, similar to *a b*, *fig.* 4; the dies, (*fig.* 6.) are now used. The circle of brass, being placed over the hole of the die L, is forced through it by the end of the other tool, K, which being smooth and of a spherical figure, causes the plate of metal to assume the same form, and fall into the drawer beneath in the state of *s*, when it is fit for use. It must be observed, that the aperture through the die, L, is as much larger than the tool K, as to admit the thickness of the metal all round it, and the upper side of the whole must not be left sharp, but rounded off, so as not to cut, but only bend the piece of metal in passing through it: also the circle of metal must be larger than the hole, that there may be a sufficiency to form the cup or hemisphere *s*. The size of this circle is shewn by the dotted circle *r*, in the plan *fig.* 6, which likewise shews a piece of brass *t*, in the form of a square; it is fastened upon the die, to guide and stop the circle in the point where it is concentric with the hole over which it is placed.

The open-work in fenders, and ornamental fire-grates, is stamped out by the fly-press. For this purpose the pattern

intended to be cut out is defcribed upon the plate of caft-fteel intended to form the fender, and by appropriate punches the holes are fucceffively cut out. In this manner the diamonds, lozenges, triangles, and other figures, we obferve in thefe articles are removed with great facility. This operation has lately received great improvement from Mr. Proctor of Sheffield. By this new method a great number of punches, and of different figures, are moved at the fame time, and the neceffity of defcribing the pattern upon the plate is obviated; whereas in the common method the fenders muft pafs through the prefs as many times as there are figures in the pattern, and it requires fome fkill and judgment in placing the fender fo correctly in its true pofition beneath the tool of the prefs, as to have no inaccuracies in the pattern difcernible to the eye.

Fig. 7. is the prefs ufed for the purpofe, though not exclufively, all heavy articles being ftamped in a prefs of this kind. The improved apparatus is feen on the ground by the fide of the prefs, where A A is the piece of fteel plate, inclofed between two leaves of a frame B, fimilar to book-lids. The leaves are two plates of fteel, hardened and tempered; the figure of D (*fig*. 8.) cut out in exactly the fame pattern as the fender is intended to be. Thefe plates are attached, by four fcrews in each, to an iron frame B, connected by hinges E; when fhut together, as at A A, the apertures in the upper and lower leaves correfpond, and the plate A is interpofed between them. A number of fteel punches of the proper figure, as T, are placed in the holes of the upper leaf, fo as to fill them all up, and the whole is placed upon the lower bed H of the prefs, and the flat iron bed I being forced down upon the punches by the fcrew, drives them all through at once, and removes correfponding pieces from the fteel plate A A. The punches fall through the plate, and are received in a fmall drawer, beneath the bed of the prefs. The fcrew being turned back, the tools and plate are removed to the table K before the prefs, the book opened, and the plate is put forwards through the leaves, fo as to cut out another length. To enfure the parallelifm and proper diftance from the former pattern, the leaves have one more hole in them than is intended to be cut out at the operation. In *fig*. 8. *a* reprefents this hole, which is brought to coincide with the hole cut by *b* at the former operation. By this means, it is certain to be in a ftraight line, and to keep it fo. A punch is put through the plate in this hole *a* before it is placed under the prefs a fecond time. The workman is feated upon the beam L, before the table K, and finds the punches, which had fallen through into the drawer, ftanding up in it in the true pofition; and he has only to transfer them to the leaves for the next ftamp. At N is fhewn another pair of leaves; and at *fig*. 9. a piece of the plate cut between them: *n*, are two of the punches; the leaves are reprefented as opened to admit the plate, and its pofition is adjufted by paffing two of the punches through the holes ftamped in the plate by the former ftroke.

The prefs (*fig*. 7.) is of large dimenfions; its frame P double to give greater ftrength; the lever R loaded at each end with heavy weights. It is many feet in length, though it is feen endways, and confequently forefhortened in the drawing. The frame S S L is placed beneath the furface of the ground, and a circular walk is made for the two men who run round with the end of the lever R, to give it as great a velocity as poffible, that its momentum may give a great energy to the action of the fcrew. The workman feated upon L, is low enough to be beneath the lever as it moves over his head. The fcrew is pointed at the lower end, and acts in a focket on the top of the flider M; to the lower end of which the moving bed I of the prefs is faftened; to balance the weight of the flider and bed, a lever X, and a heavy weight Y, are applied, which raifes them up when the fcrew is turned back, fo as to admit the work being placed beneath the prefs.